Biological Evaluation of Washington's Freshwater Ammonia Acute Water Quality Standard

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1. Introduction

Section 7(a)(2) of the Endangered Species Act ("ESA"), 16 U.S.C. section 1536(a), requires that federal agencies shall, in consultation with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) (together, these two agencies are referred to as "the Services"), insure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat. A biological evaluation provides an analysis of the potential effects of a federal agency action on any proposed and listed species or the designated critical habitat of any such species based on the best scientific or commercial information available.

The Environmental Protection Agency (EPA) has developed this Biological Evaluation (BE) to assist with the ESA section 7 consultation and to satisfy the Magnuson-Stevens Fishery Conservation and Management Act for EPA's previous approval of the 2006 revisions to Washington Department of Ecology's (Ecology) ammonia criteria (WAC 173-240(3)). The criteria and approval language can be found in section 1.4, EPA's 2008 Approval Subject to this Consultation.

1.1 Agency Action and Definition of the Action Area

The federal action that is the subject of this BE is EPA's February 11, 2008 approval of Washington's 2006 revised acute ammonia criteria for freshwater. The revised freshwater acute criteria for ammonia are part of Washington's water quality standards (WQS) adopted by Ecology on November 20, 2006 and submitted to EPA for review and action in accordance with Section 303(c) of the Clean Water Act (CWA) on December 8, 2006. Washington's 2006 ammonia criteria became effective for purposes of the CWA upon EPA's approval.

Under the CWA, state WQS apply to surface waters within state boundaries. The action area that is the subject of this consultation includes all freshwaters of the United States within the state of Washington's jurisdiction.

1.2 Overview of Water Quality Standards

A WQS defines the water quality goals of a water body by designating the use or uses of the water, by setting criteria necessary to protect those uses, and by preventing degradation of water quality through antidegradation provisions. The CWA provides the statutory basis for the WQS program and defines water quality goals. For example, CWA Section 101(a) states, in part, that wherever attainable, waters should achieve a level of quality that "provides for the protection and propagation of fish, shellfish and wildlife, and provides for recreation in, and on the water" (the "fishable/swimmable" goal of the CWA).

The WQS regulations (40 CFR 131) set forth specifications for the WQS program as well as the minimum requirements for a state/tribal WQS submission to EPA for review and action. The regulations allow states/tribes to adopt discretionary policies such as provisions that authorize mixing zones and compliance schedules. These policies are also subject to EPA review and action.

States/tribes have the primary responsibility for developing appropriate designated uses. These uses reflect the water quality goal(s) for the water body. The state/tribe then sets water quality criteria for a number of parameters which will provide for a level of water quality in the water body such that the designated uses can be attained and protected. Under CWA Section 304(a), EPA publishes criteria documents as guidance to states/tribes. States/tribes consider these national criteria documents, along with any additional relevant scientific information, when adopting their regulatory ambient water quality criteria.

Aquatic life water quality criteria are typically expressed in two forms, with different recommended magnitude and duration: 1) acute criteria (the subject of this BE) are intended to protect against mortality or effects that occur due to a short-term exposure to a chemical and 2) chronic criteria (not the subject of this BE) are intended to protect against survival, growth and reproductive effects that may occur due to a longer-term exposure to a chemical. Both the acute and chronic criteria have three components: criterion magnitude (i.e., the criterion maximum concentration (CMC) for acute criteria and criterion continuous concentration (CCC) for chronic criteria), duration of the CMC and CCC (i.e., averaging period), and a maximum allowable frequency of exceedance of the CMC and CCC. For aquatic life criteria based on standard laboratory toxicity tests (e.g., 48 hour acute toxicity tests involving continuous chemical exposure to invertebrates and 96 hour acute toxicity tests involving continuous chemical exposure to vertebrates), the EPA typically recommends average durations of one hour for the CMC and four days for the CCC. The EPA typically recommends a maximum frequency of exceedance of not more than once in three years, on average, to allow for ecosystem recovery (USEPA 2017).

Once the standards are officially adopted by the state/tribe, they are submitted to EPA for review and subsequent approval (or disapproval) under CWA Section 303(c). EPA reviews the standards to determine whether they are consistent with EPA regulations and guidance and whether the designated uses and criteria are protective. EPA then makes a determination whether the WQS meet the requirements of the CWA and 40 CFR 131 and formally notifies the state/tribe of these results. If EPA determines that the WQS are consistent and meet the requirements of the CWA, EPA approves the standards and they become effective for CWA purposes. This means that the WQS can be used, for example, in establishing requirements in National Pollutant Discharge Elimination System (NPDES) permits, Total Maximum Daily Load (TMDL) analyses for impaired waters, and/or CWA Section 404 wetland permits.

If EPA determines that any such revised or new WQS is not consistent with the applicable requirements of the CWA, EPA is required to specify the disapproved portions and the changes needed in order to meet the requirements. The state/tribe is then given an opportunity to make those appropriate changes. If the state/tribe does not adopt the required changes, 40 CFR 131 requires that EPA promulgate federal regulations to replace those disapproved portions of the state/Tribal WQS.

1.3 Background and Project History

In August 2003, Ecology adopted, and submitted to EPA, several WQS regulations revisions. The WQS submittal contained the specific revisions to the regulatory language at Washington Administrative Code (WAC) 173-201A, the Lt. Governor's certification that the revisions were duly adopted in accordance with State law, a summary of the changes made to the State’s WQS, the State's response to comments document, and technical reports. On March 22, 2006, EPA sent a letter to Ecology disapproving a portion of the WQS revisions unrelated to ammonia.

As a result of EPA's action on March 22, 2006, Ecology revised the state's WQS to address the deficiencies outlined in EPA's disapproval action. Ecology's revised WQS were submitted to EPA on December 8, 2006. The submittal contained revisions to the State's WQS, the Lt. Governor's certification that the revisions were duly adopted in accordance with State law, and a summary of the changes made to the WQS.

On February 11, 2008, EPA provided its determination on the remaining provisions in the 2003 and 2006 packages including the acute freshwater ammonia criteria.

On February 10, 2014, the Northwest Environmental Advocates filed a complaint in U.S. District Court for the Western District of Washington (Case No. 2:14-cv-0196-RSM) challenging, in part, that EPA did not complete section 7 consultation on the acute freshwater ammonia criteria that was part of EPA's February 11, 2008 WQS action. On October 17, 2018, the Court issued a Stipulated Dismissal stating:

Within three years of the Court's entry of this Stipulated Dismissal, EPA will complete an effects determination pursuant to 50 C.F.R. § 402.14(a) for its approval of Washington's December 8, 2006 submission of revisions to the State's ammonia criteria and, as appropriate, request initiation of any necessary ESA section 7 consultation with the U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service. Provided, however, that if Washington submits revisions to the ammonia criteria for EPA's review pursuant to CWA section 303(c) and EPA proposes to approve such revisions, then EPA will instead, within one year of such submission or within three years of the Court's approval of this Stipulated Dismissal, whichever date is later, complete an effects determination for its proposed approval of Washington's submission of revised ammonia criteria (rather than the criteria approved by EPA on February 11, 2008) and will, as appropriate, request initiation of any necessary ESA section 7 consultation with the U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service.

As of the date of the final BE, Ecology has not updated the acute ammonia criteria for Washington.

Table 1-1. Consultation History and Milestones

In order to meet the Court deadline of completing an effects determination within three years (or by October 17, 2021), EPA began the early engagement with the Services in mid-2020. Below is an outline of the outreach to the Services by EPA and coordination with Ecology during the BE development process.

Date	Consultation Action
June 11, 2020	Ecology requests applicant status.
June 15, 2020	EPA recognizes Ecology's applicant status.
July 28, 2020	Email from Hanh Shaw to Ryan McReynolds (USFWS) asking for a conversation regarding beginning ESA consultation on WA's ammonia WQS.

Date	Consultation Action
August 19, 2020	Email from Hanh Shaw to Elizabeth Babcock (NMFS) and cc to Ryan McReynolds outlining EPA's action and the need for consultation. Also requests a meeting with both Services to discuss baseline.
October 8, 2020	Project Introductory Meeting with Elizabeth Babcock.
October 30, 2020	Emails from Hanh Shaw to Ryan McReynolds and Elizabeth Babcock requesting confirmation of the List of Species and Designated Critical Habitat Areas.
January 19, 2021	Email from Ryan McReynolds to Hanh Shaw confirming list and indicating EPA should be using IPAC for the species list.
April 28, 2021	Email from Jeff Vanderpham to Mark Jankowski indicating that salmonids are the best surrogate for eulachon and sending references.
July 15, 2021	Email from Frankie Johnson (NMFS) to Hanh Shaw responding to the October 20, 2020 request for confirmation of List of Species and Designated Critical Habitat Areas.
August 5, 2021	Email from Chad Brown to Lindsay Guzzo clarifying the action area to be only freshwater as defined by Ecology's WQS. The freshwater criteria must be applied at any point where ninety-five percent of the salinity values are less than or equal to one part per thousand.
September 28, 2021	Meeting with Elizabeth Babcock, Donald Hubner (NMFS), and Ryan McReynolds to walk through the components of the BE and effects analyses.
October 14, 2021	Emails from Hanh Shaw to Elizabeth Babcock and Ryan McReynolds transmitting the BE and requesting concurrence.

1.4 EPA's 2008 Approval Language Covered by this Consultation

WQS Provision: WAC 173-240(3)(note f): Shall not exceed the numerical value in total ammonia nitrogen (mg N/L) given by:

$$\underline{\text{For salmonids present:}}\ \underline{\frac{0.275}{1+10^{7.204-pH}}+\frac{39.0}{1+10^{pH-7.204}}}$$

$$\underline{\text{For salmonids absent:}}\ \underline{\frac{0.411}{1+10^{7.204-pH}}+\frac{58.4}{1+10^{pH-7.204}}}$$

EPA ACTION: This note is part of Table 240(3) and is referenced as Washington's freshwater acute criteria for ammonia. The note provides the equations for calculating Washington's acute criteria for ammonia.

EPA approves, subject to completion of ESA consultation, Washington's revised acute ammonia criteria for freshwaters as consistent with the CWA and implementing regulations at 40 C.F.R. 131.11(a) which require that criteria be sufficient to protect the designated uses established by the State.

Washington's revised freshwater aquatic life acute ammonia criteria are identified in Table 240(3), note f of its WQS. The criteria consist of two equations: an equation which applies where salmonids are present, and a second equation which applies where salmonids are absent. These equations are consistent with EPA's most recent CWA Section 304(a) recommended freshwater aquatic life acute ammonia criterion value. (EPA, 1999. *1999 Update of Ambient Water Quality*

Criteria for Ammonia. EPA-822-R-99-014) Therefore, EPA approves these criteria as consistent with EPA's 304(a) criteria recommendations and as protective of designated uses in waters of Washington state.

2. Species Present in the Action Area and May Affect Determinations

Tables 3 and 4 list the endangered (E) and threatened (T) species that are evaluated in this BE and any critical habitat that has been designated (D) for those species. The list (October 2020) was developed with input from the Services and is based on the action area (section 1.1).

The "May Affect" or "No Effect" determinations assess whether an ESA listed species or its critical habitat may be exposed to the proposed action. This is discussed further in the effects analysis and determinations.

Table 2-1. May Affect Determinations for Species Managed by USFWS

Species	Status	Critical Habitat
Oregon Spotted Frog *Rana pretiosa*	T	Designated
Marbled Murrelet *Brachyramphus marmoratus*	T	Designated
Bull Trout *Salvelinus confluentus*	T	Designated

Table 2-2. May Affect Determinations for Species Managed by NMFS

Species	Status	Critical Habitat
Green Sturgeon (Southern DPS) *Acipenser medirostris*	T	Designated
Eulachon (Southern DPS) *Thaleichthys pacificus*	T	Designated
Southern Resident Killer Whale (Southern Resident) *Orcinus orca*	E	Designated
Coho Salmon (Lower Columbia River) *Oncorhynchus kisutch*	T	Designated
Chum Salmon (Columbia River) *Oncorhynchus keta*	T	Designated
Chum Salmon (Hood Canal, summer) *Oncorhynchus keta*	T	Designated
Chinook Salmon (Upper Columbia River, spring run) *Oncorhynchus tshawytscha*	E	Designated
Chinook Salmon (Snake River, spring/summer runs) *Oncorhynchus tshawytscha*	T	Designated
Chinook Salmon (Snake River, fall run) *Oncorhynchus tshawytscha*	T	Designated

Species	Status	Critical Habitat
Chinook Salmon (Upper Willamette River) *Oncorhynchus tshawytscha*	T	Not Designated
Chinook Salmon (Puget Sound) *Oncorhynchus tshawytscha*	T	Designated
Chinook Salmon (Lower Columbia River) *Oncorhynchus tshawytscha*	T	Designated
Sockeye Salmon (Snake River) *Oncorhynchus nerka*	E	Designated
Sockeye Salmon (Ozette Lake) *Oncorhynchus nerka*	T	Designated
Steelhead (Upper Columbia River) *Oncorhynchus mykiss*	T	Designated
Steelhead (Snake River Basin) *Oncorhynchus mykiss*	T	Designated
Steelhead (Middle Columbia River) *Oncorhynchus mykiss*	T	Designated
Steelhead (Upper Willamette River) *Oncorhynchus mykiss*	T	Designated
Steelhead (Puget Sound) *Oncorhynchus mykiss*	T	Designated
Steelhead (Lower Columbia River) *Oncorhynchus mykiss*	T	Designated

Table 2-3. No Effect Determinations for Species Managed by NMFS

Species	Justification for No Effect determination
Bocaccio *Sebastes paucispinis*	These are marine organisms the feed from marine diets. Therefore, these species will not be affected by the freshwater acute ammonia water quality standard approval action.
Yelloweye Rockfish (*Puget Sound/Georgia Basin DPS)* *Sebastes ruberrimus*	
Blue Whale *Balaenoptera musculus*	
Fin Whale *Balaenoptera physalus*	
Gray Whale *Eschrichtius robustus*	
Green Turtle (East Pacific DPS) *Chelonia mydas*	
Humpback Whale (Central America DPS) *Megaptera novaeangliae*	
Humpback Whale (Mexico DPS) *Megaptera novaeangliae*	

Species	Justification for No Effect determination
Leatherback Turtle *Dermochelys coriacea*	
Loggerhead Turtle (North Pacific Ocean DPS) *Caretta caretta*	
North Pacific Right Whale *Eubalaena japonica*	
Sei Whale *Balaenoptera borealis*	
Sperm Whale *Physeter macrocephalus*	

Table 2-4. No Effect Determinations for Species Managed by USFWS

Species	Justification for No Effect determination
Canada Lynx *Lynx canadensis*	These are terrestrial species that are not aquatic-dependent organisms.
Pygmy Rabbit (Columbia Basin DPS) *Brachylagus idahoensis*	
Columbian White-Tailed Deer (Columbia River DPS) *Odocoileus virginianus leucurus*	
Grizzly Bear *Ursus arctos horribilis*	
Olympia Pocket Gopher *Thomomys mazama pugetensis*	
Roy Prairie Pocket Gopher *Thomomys mazama glacialis*	
Tenino Pocket Gopher *Thomomys mazama tumuli*	
Woodland Caribou (Southern Mountain Caribou DPS) *Rangifer tarandus ssp. caribou*	
Yelm Pocket Gopher *Thomomys mazama yelmensis*	
Northern Spotted Owl *Strix occidentalis caurina*	
Short-tailed Albatross *Phoebastria (=Diomedea) albatrus*	This is a marine and pelagic species and utilizes marine dietary sources.
Streaked Horned Lark *Eremophila alpestris strigata*	This terrestrial species primarily utilizes terrestrial dietary sources.

Species	Justification for No Effect determination
Western Snowy Plover (Pacific Coast Population DPS) *Charadrius nivosus nivosus*	This terrestrial species ranges in marine habitats and utilizes terrestrial and marine dietary sources.
Yellow-billed Cuckoo (Western DPS) *Coccyzus americanus*	This terrestrial species primarily utilizes terrestrial dietary sources.
Island Marble Butterfly *Euchloe ausonides insulanus*	These are terrestrial insects.
Oregon Silverspot Butterfly *Speyeria zerene hippolyta*	
Taylor's Checkerspot *Euphydryas editha taylori*	
Golden Paintbrush *Castilleja levisecta*	Plants are insensitive to ammonia toxicity and none of these species are aquatic.
Kincaid's Lupine *Lupinus sulphureus ssp. kincaidii*	
Marsh Sandwort *Arenaria paludicola*	
Nelson's Checker-mallow *Sidalcea nelsoniana*	
Showy Stickseed *Hackelia venusta*	
Spalding's Catchfly *Silene spaldingii*	
Umtanum Desert Buckwheat *Eriogonum codium*	
Ute Ladies'-tresses *Spiranthes diluvialis*	
Wenatchee Mountains Checkermallow *Sidalcea oregana var. calva*	
White Bluffs Bladderpod *Physaria douglasii ssp. tuplashensis*	
Whitebark Pine *Pinus albicaulis*	

3. Washington State Species Profiles

The species profiles in this section are modified from the Biological Assessment for the Northwest Area Contingency Plan for the Response to Spills of Oil and Hazardous Substances (USEPA 2018).

3.1 U.S. Fish and Wildlife Service Managed Species

3.1.1 Marbled Murrelet (*Brachyramphus marmoratus*)

The marbled murrelet was listed as a threatened species on October 1, 1992, in Washington, Oregon, and northern California (57 FR 45328). The marbled murrelet is a small diving seabird that nests mainly in coniferous forests and forages in nearshore marine habitats. Males and females have sooty-brown upper parts with dark bars. Underparts are light, mottled brown. Winter adults have brownish-gray upper parts and white scapulars (shoulders). The plumage of fledged young is similar to that of adults in winter. Chicks are downy and tan-colored with dark speckling (USEPA and USCG 2015).

A population abundance estimate in 2017 for the Washington, Oregon and California was about 23,000 murrelets. From 2000-2018, there was no evidence for a linear trend overall for these sates (0.3 percent per year), however, for Washington there was strong evidence for a declining linear trend in Washington (-3.9 percent per year) (William R. McIver and Deanna Lynch 2020).

Surveys indicate highest nesting presence is on the Olympic Peninsula, the northern Cascades and in limited remaining habitat in southwest Washington. At-sea population monitoring from 2001 to 2015 indicated a 4.4% decline in the murrelet population annually, which represents a 44% reduction since 2001. The 2015 population estimate for Washington is about 7,500 birds. Sustained low juvenile recruitment has been identified as a main cause of the decline. https://wdfw.wa.gov/species-habitats/species/brachyramphus-marmoratus#desc-range

3.1.1.1 Species Distribution

Historically, the breeding range of the marbled murrelet extends from Alaska through British Columbia, Washington, Oregon, to northern Monterey Bay in central California. This species winters throughout its breeding range and also occurs in small numbers off southern California (USFWS 2015).

At the time of listing, the distribution of active nests in nesting habitat was described as noncontinuous (USFWS 1997b, a). The at-sea extent of the species currently encompasses an area similar in size than the species' historic distribution.

3.1.1.2 Critical Habitat

On May 24, 1996, the USFWS designated critical habitat for the marbled murrelet encompassing approximately 1.6 ha (4.0 million acres) across Washington (647,797 ha [160,741 acres]), Oregon (607,028 ha [1.5 million acres]), and California (283,278 ha [699,995 acres]) (17 FR 26256).

The Final Rule revising critical habitat for the marbled murrelet was published on October 5, 2011 (76 FR 61599). The USFWS reduced critical habitat in Northern California and Oregon. New data indicated that these areas did not meet the definition of critical habitat, and 76,751 ha (189,656 acres) were removed from the critical habitat designated in 1996 (76 FR 61599).

The USFWS revisited the critical habitat designation for the marbled murrelet on August 4, 2016 (81 FR 51348). The USFWS concluded that the current (2006 and 2011) designations for critical habitat met satisfactory requirements for the species. Currently, there are approximately 1.5 million ha (3.7 million acres) of designated critical habitat in Washington, Oregon, and California. The critical habitat in Washington overlaps with the Action Area.

The Physical and Biological Features (PBFs) considered essential to the conservation of the marbled murrelet are those features critical for supporting suitable nesting habitat for successful reproduction. Those features are:

- Individual trees with potential nesting platforms
- Forested areas within 0.8 km (0.5 miles) of individual tress with potential nesting platforms, and with a canopy height of at least one-half the site-potential tree height.

3.1.1.3 Life History

Marbled murrelets spend most of their lives in the marine environment where they forage in near-shore areas and consume a diversity of prey species, including small fish and invertebrates. In their terrestrial environment, the presence of platforms (large branches or deformities) used for nesting is the most important characteristic of their nesting habitat. Murrelet habitat use during the breeding season is positively associated with the presence and abundance of mature and old growth forests, large core areas of old growth, low amounts of edge habitat, reduced habitat fragmentation, proximity to the marine environment, and forests that are increasing in stand age and height (USFWS 2015).

Nest stands are typically composed of low elevation conifer species. In California, nest sites have been located in stands containing old growth redwood (*Sequoia sempervirens*) and Douglas-fir, while nests in Oregon and Washington have been located in stands dominated by Douglas-fir, western hemlock, and Sitka spruce (USFWS 2015).

In areas with protective waters, there may be a general opportunistic shift from exposed outer coasts into more protected waters during the winter (Nelson 1997); for example, many marbled murrelets breeding on the exposed outer coast of Vancouver Island appear to congregate in the more sheltered waters within the Puget Sound and the Strait of Georgia in fall and winter (Burger 1995).

Murrelets are usually found within 8 km (5 miles) of shore, and in water less than 60 m (197 ft) deep (Ainley et al. 1995, Burger 1995, Nelson 1997). In general, this species occurs closer to shore in exposed coastal areas and farther offshore in protected coastal areas (Nelson 1997). Courtship, foraging, loafing, molting, and preening occur in marine waters.

Marbled murrelets are wing-propelled pursuit divers that forage both during the day and at night (Carter and Sealy 1986a, Carter and Sealy 1986b, Kuletz 2005). This species can make substantial changes in foraging sites within the breeding season, but many individuals routinely forage in the same general areas and at productive foraging sites, as evidenced by repeated use over a period of time throughout the breeding season (Carter and Sealy 1986a, Whitworth et al. 2000, Hull et al. 2001, Mason et al. 2002, Piatt et al. 2007). Murrelets are also known to forage in freshwater lakes (Nelson 1997). Activity patterns and foraging locations are influenced by biological and physical processes that concentrate prey, such as weather, climate, time of day, season, light intensity, upwelling, tidal rips, narrow passages between island, hallow banks, and kelp beds (Ainley et al. 1995, Burger 1995, Nelson 1997).

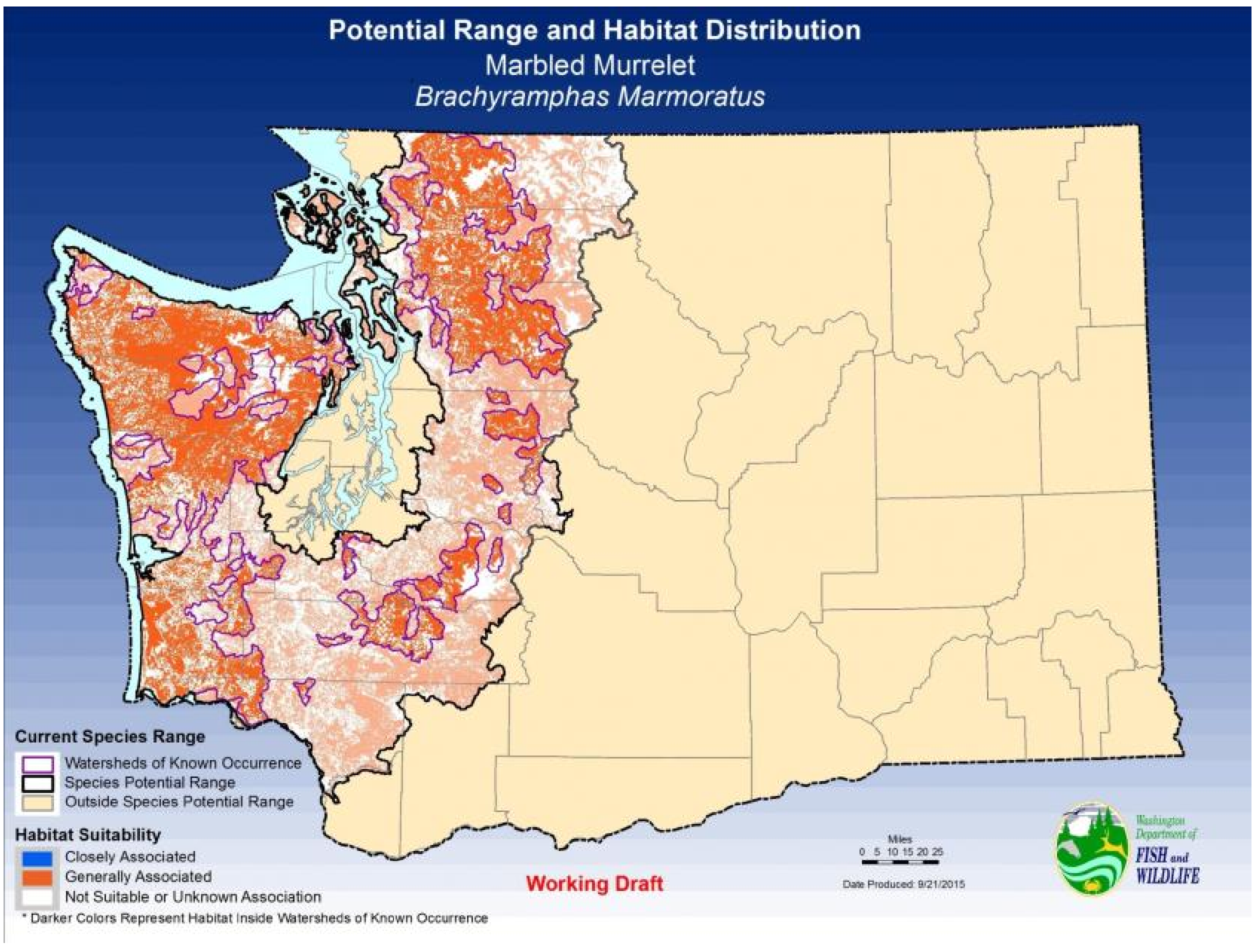
Throughout their range, marbled murrelets are opportunistic feeders and utilize prey of diverse sizes and species. They feed primarily on fish and invertebrates in marine waters, although they have also been detected on rivers and inland lakes (50 CFR 17) (Carter and Sealy 1986a). In general, small schooling fish and large pelagic crustaceans are the species' main prey items. Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), immature Pacific herring (*Clupea harengus*), capelin (*Mallotus villosus*), Pacific sardine (*Sardinops sagax*), juvenile rockfishes (*Sebastas* spp.), and surf smelt (*Osmeridae*) are the most common fish species taken. Squid (*Loligo* spp.), euphausiids, mysid shrimp, and large pelagic amphipods are the main invertebrate prey. Marbled murrelets are able to shift their diet in response to prey availability (Becker et al. 2007). Long-term adjustment to less energy-rich prey resources appears to be partly responsible for poor reproduction in California (USFWS 2015).

Breeding adults exercise more specific foraging strategies when feeding chicks, usually carrying a single, energy-rich fish to their chicks (Burkett 1995a, Burkett 1995c, Nelson 1997). Freshwater prey is important to some individuals during several weeks in summer and may facilitate more frequent chick feedings (Hobson 1990a, Hobson 1990b). Nesting marbled murrelets that are returning to their nest at least once per day must balance the energetic costs of foraging trips; this may result in their preferring to forage in marine areas in close proximity to their nesting habitat. However, if adequate or appropriate foraging resources are unavailable in close proximity to their nesting areas, the species may be forced to forage at greater distances or abandon their nests (Huff et al. 2006b, Huff et al. 2006a). As a result, the distribution and abundance of prey suitable for feeding chicks may greatly influence the overall foraging behavior and location during the nesting season and may affect reproductive success (Becker et al. 2007). It may also significantly affect the energy demand on adults by influencing both the foraging time and number of trips required (Kuletz 2005).

3.1.1.4 Current Stressors and Threats

Several anthropogenic threats were identified as having caused the dramatic decline in the species when the marbled murrelet was listed under the ESA (57 FR 45328) and in the Recovery Plan (USFWS 1997b, a). These threats include habitat destruction and modification in the terrestrial environment from timber harvest and human development, which caused a severe reduction in the amount of nesting habitat, unnaturally high levels of predation resulting from forest edge effects, the existing regulatory mechanisms, inadequate regulatory mechanisms, and human-caused factors such as mortality from oil spills and entanglement in fishing nets used in gill-net fisheries.

There have been changes in the levels of these threats since the 1992 listing (USFWS 2004, 2009). The regulatory mechanisms implemented since 1992 that affect land management in Washington, Oregon, and California, and new gill-netting regulations in northern California and Washington, have reduced some threats to the marbled murrelet (USFWS 2004). However, the levels for the other threats identified in the 1992 listing (57 FR 45328), including the loss of nesting habitat, predation rates, and mortality risks from oil spills and (including gill net fisheries), have remained unchanged. However, new threats have been identified (USFWS 2009). These new stressors are due to several environmental factors that may be affecting marbled murrelets in the marine environment, including habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support the species due to elevated levels of polychlorinated biphenyls in prey species; changes in prey abundance and availability; changes in prey quality; harmful algal blooms that produce biotoxins leading to mortality; and climate change in the Pacific Northwest.



Source: https://wdfw.wa.gov/species-habitats/species/brachyramphus-marmoratus#desc-range

Figure 3-1. Potential Range and Habitat Distribution of Marbled Murrelet.

Human factors that affect the continued existence of the species include derelict fishing gear leading to mortality from entanglement, energy development projects (wave, tidal, and on-shore wind energy projects) leading to mortality, and disturbance in the marine environment (from exposures to lethal and sublethal levels of high underwater sound pressures caused by piledriving, underwater detonations, and potential disturbance from high vessel traffic) (USFWS 2009).

Climate change is expected to further exacerbate some existing threats such as the projected potential for increased habitat loss from drought-related fire, mortality, insects and disease, and increases in extreme flooding, landslides and windthrow events in the short term (10 to 30 years) (USFWS 2009).

3.1.2 Oregon Spotted Frog (*Rana pretiosa*)

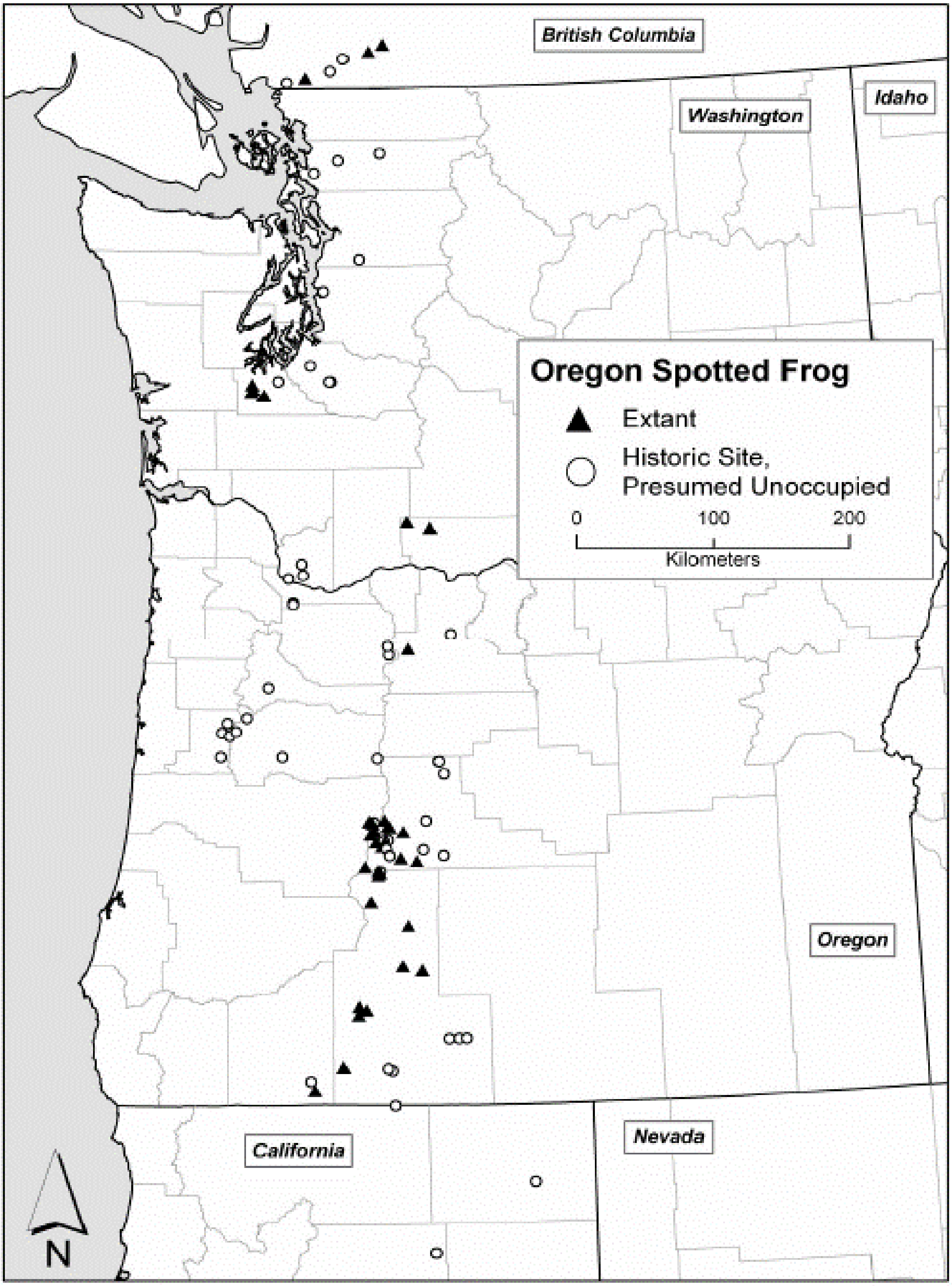
The Oregon spotted frog was listed as threatened on August 29, 2014 (79 FR 51657). This species is named for the black spots that cover the head, back, sides, and legs. The dark spots are characterized by ragged edges and light centers that grow and darken with age (Hallock 2013). Body color also varies with age. Juveniles are usually brown or, occasionally, olive green on the back and white, cream, or flesh-colored with reddish pigments on the underlegs and abdomen, developing with age (McAllister and Leonard 1997). Adults range from brown to reddish brown but tend to become redder with age. The Oregon spotted frog is medium-sized, ranging from 4.3 to 10.1 cm (1.7 to 4 inches) in body length. Females are typically larger than males and can reach up to 10 cm (4 inches) or more (79 FR 51657).

3.1.2.1 Species Distribution

Historically, the Oregon spotted frog ranged from British Columbia to the Pit River basin in northeastern California (McAllister and Leonard 1997). Oregon spotted frogs have been documented at 61 historical localities in 48 watersheds (three in British Columbia, 13 in Washington, 29 in Oregon, and three in California) in 31 sub-basins (McAllister and Leonard 1997, COSEWIC 2011b) (79 FR 51657).

Currently, the Oregon spotted frog is found within 15 sub-basins, ranging from extreme southwestern British Columbia south through the Puget Trough, and the Cascades Range from south-central Washington to at least the Klamath Basin in southern Oregon (Figure 3-2). Oregon spotted frogs occur in lower elevations in British Columbia and Washington and are restricted to high elevations in Oregon (Pearl et al. 2010).

In Washington, Oregon spotted frogs are known to occur only within six sub-basins/watersheds: the Sumas River, a tributary to the Lower Chilliwack River watershed and Fraser River sub-basin; the Black Slough in the lower South Fork Nooksack River, a tributary of the Nooksack River; the Samish River; the Black River, a tributary of the Chehalis River; Outlet Creek (Conboy Lake), a tributary to the Middle Klickitat River; and Trout Lake Creek, a tributary of the White Salmon River. The Klickitat and White Salmon Rivers are tributaries to the Columbia River. The Oregon spotted frogs in each of these sub-basins/watersheds are isolated from frogs in other sub-basins (79 FR 51657).



Source: (Cushman and Pearl 2007)

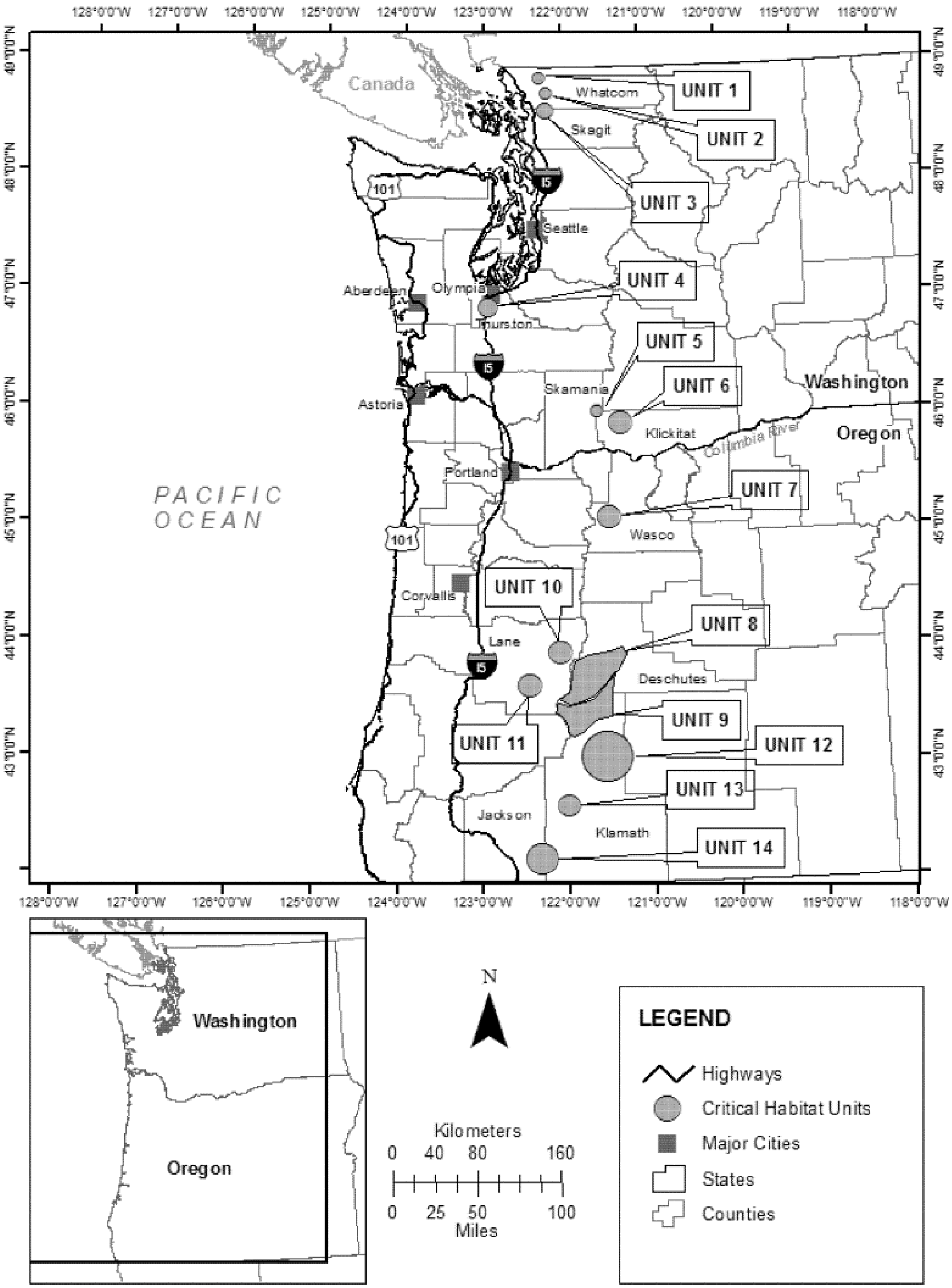
Figure 3-2. Distribution of Oregon Spotted Frog in the Pacific Northwest.

3.1.2.2 Critical Habitat

The USFWS designated critical habitat for the Oregon spotted frog of 26,319 ha (65,036 acres) and 32.7 stream km (20.3 stream miles) in Washington and Oregon on May 11, 2016 (81 FR 29335) (Figure 3-3). Critical habitat for the Oregon spotted frog is within 14 units, delineated by river sub-basins where spotted frogs are extant: (1) Lower Chilliwack River; (2) South Fork Nooksack River; (3) Samish River; (4) Black River; (5) White Salmon River; (6) Middle Klickitat River; (7) Lower Deschutes River; (8) Upper Deschutes River; (9) Little Deschutes River; (10) McKenzie River; (11) Middle Fork Willamette River; (12) Williamson River; (13) Upper Klamath Lake; and (14) Upper Klamath. Descriptions of ownership, acreages, and threats for each unit are stated in the critical habitat designation (81 FR 29335).

The PBFs determined to be essential to the conservation of Oregon spotted frog critical habitat include:

- Ephemeral or permanent bodies of freshwater with the following characteristics for nonbreeding, breeding, rearing, and overwintering habitat:
    - Breeding and rearing habitat – inundated for a minimum of 4 months per year (timing varies by elevation)
    - Overwintering habitat – inundated from October through March
    - Breeding and rearing habitat – ephemeral waterbodies are hydrologically connected by surface water flow to a permanent waterbody
    - Breeding and rearing habitat – shallow water areas (<30 cm [<12 in]) or water of this depth over vegetation in deeper water
    - Nonbreeding habitat – total surface area <50% vegetative cover
    - Breeding and rearing habitat – gradual topographic gradient (<3% slope) from shallow water toward deeper in permanent water
    - Breeding and rearing habitat – herbaceous wetland vegetation or structurally similar
    - Breeding and rearing habitat – shallow water areas with high solar exposure or low (short) canopy cover
    - Breeding, rearing, and nonbreeding habitat – absence or low density of nonnative predators
- Ephemeral or permanent freshwater bodies with aquatic movement corridors with the following characteristics:
    - Linear distance from breeding areas <5 km (3.1 mi.)
    - Impediment free (including, but not limited to, hard barriers such as dams, impassable culverts, lack of water, or biological barriers such as abundant predators or lack of refugia from predators).
- Refugia habitat that includes sufficient dense vegetation and/or an abundance of woody debris in breeding, rearing, nonbreeding, and overwintering habitat.to provide refugia from predators.



Source: 81 FR 29335 (Unit maps are located in the federal register notice.)

Figure 3-3. Critical Habitat for Oregon Spotted Frog in Washington and Oregon.

3.1.2.3 Life History

The Oregon spotted frog is highly aquatic; it is almost always found in or near a perennial body of water that includes zones of shallow water and abundant emergent or floating aquatic plants, which it uses for basking and cover. Conditions required for completion of the species' life cycle are shallow water areas for egg and tadpole survival; perennially deep, moderately vegetated pools for adult and juvenile survival in the dry season; and perennial water for protecting all age classes during cold, wet weather (Watson et al. 2003).

Oregon spotted frogs breed in shallow pools near flowing water or in shallow pools that may be connected to larger bodies of water during seasonally high water or at flood stage. These locations are most often defined by shallow, often temporary, pools of water; gradually receding shorelines; location on benches of seasonal lakes and marshes; or location in wet meadows. These sites are usually associated with the previous year's emergent vegetation and are generally no more than 36 cm (14 in) deep (Pearl and Hayes 2004).

Oregon spotted frogs concentrate breeding efforts in relatively few locations (McAllister and White 2001). The availability of the unique characteristics of egg-laying sites is limited, and adults may have limited flexibility to switch sites. This inflexibility may make the Oregon spotted frog particularly vulnerable to modification of egg-laying sites (79 FR 51657).

After breeding, during the dry season, Oregon spotted frogs move to deeper, permanent pools or creeks, where they are often observed near the water surface basking and feeding in beds of floating and submerged vegetation (Watson et al. 2003). Larger sites are more likely to provide the seasonal microhabitats required by Oregon spotted frogs, have a more reliable prey base, and include overwintering habitat. It is thought that a minimum wetland size of 3.6 ha (8.9 ac) may be necessary to reach suitably warm temperatures and support a large enough population to persist despite high predation rates (Hayes 1994). However, Oregon spotted frogs also occupy smaller sites and are known to occur at sites as small as 1 ha (2.5 ac) and as large as 1,989 ha (4,915 ac) (Pearl and Hayes 2004). Smaller sites generally have a small number of frogs and, as described above, are more vulnerable to extirpation. (Pearl and Hayes 2004) believe that these smaller sites were historically subpopulations within a larger breeding complex and that Oregon spotted frogs may only be persisting in these small sites because the sites exchange migrants or because seasonal habitat needs are provided nearby.

Known overwintering sites for the Oregon spotted frog are associated with flowing systems, such as springs and creeks, that provide water with high oxygen content (Hayes et al. 2001, Tattersall and Ultsch 2008b) and sheltering locations protected from predators and freezing (Watson et al. 2003). Oregon spotted frogs burrow in mud, silty substrate, clumps of emergent vegetation, woody accumulations within the creek, and holes in creek banks when inactive during periods of prolonged or severe cold (McAllister and Leonard 1997, Watson et al. 2003). They are intolerant of anoxic conditions and are unlikely to burrow into the mud for more than a day or two because survival under anoxic conditions is only a matter of four to seven days (Tattersall and Ultsch 2008b). This species remains active during the winter and selects microhabitats that can support aerobic metabolism and minimize exposure to predators (Tattersall and Ultsch 2008b, Tattersall and Ultsch 2008a).

Oregon spotted frog tadpoles are grazers, having rough tooth rows for scraping plant surfaces and ingesting plant tissue and bacteria. They also consume algae, detritus, and probably carrion. Post-metamorphic spotted frogs feed on live animals, primarily insects (Hallock 2013).

3.1.2.4 Current Stressors and Threats

Large historical losses of wetland habitat have occurred across the range of the Oregon spotted frog. Wetland losses are estimated at 30% to 85% across the species' range, with the greatest percentage lost having occurred in British Columbia. These wetland losses have directly influenced the current fragmentation and isolation of remaining Oregon spotted frog populations (79 FR 51657). The historical loss of Oregon spotted frog habitat and lasting anthropogenic changes in natural disturbance processes are exacerbated by the introduction of reed canarygrass (*Phalaris arundinacea*), nonnative predators, and, potentially, climate change.

In the Final Rule to list the frog as threatened, the USFWS determined that the Oregon spotted frog is impacted by one or more of the following factors to the extent that the species meets the definition of a threatened species under the ESA:

- Habitat necessary to support all life stages continuing to be impacted and/or destroyed by human activities that result in the loss of wetlands to land conversions;
- Hydrologic changes resulting from operation of existing water diversions/manipulation structures, new and existing residential and road developments, drought, and removal of beavers (Castor canadensis);
- Changes in water temperature and vegetation structure resulting from reed canarygrass invasions, plant succession, and restoration plantings;
- Increased sedimentation, increased water temperatures, reduced water quality, and vegetation changes resulting from the timing and intensity of livestock grazing (or, in some instances, removal of livestock grazing at locations where it maintains early seral stage habitat essential for breeding);
- Predation by nonnative species, including nonnative trout and bullfrogs;
- Inadequate existing regulatory mechanisms that result in significant negative impacts such as habitat loss and modification; and
- Other natural or manmade factors, including small and isolated breeding locations, low connectivity, low genetic diversity within occupied sub-basins, and genetic differentiation between sub-basins.

3.1.3 Bull Trout (*Salvelinus confluentus*)

The coterminous US population of bull trout was listed as threatened on November 1, 1999 (64 FR 58910).

3.1.3.1 Distribution

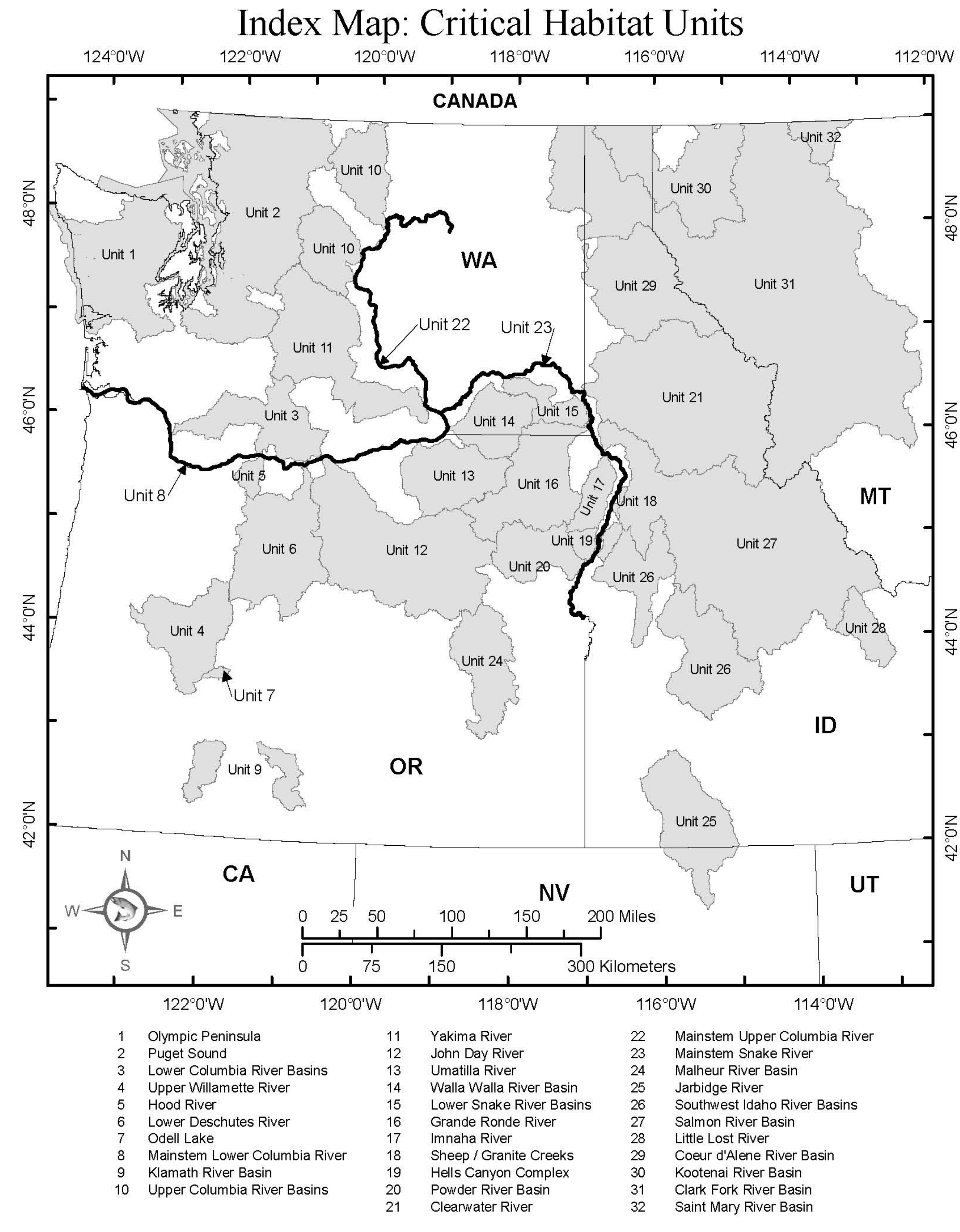
Bull trout generally occur in the Klamath River Basin of south-central Oregon; the Jarbidge River in Nevada; the Willamette River Basin in Oregon; Pacific Coast drainages of Washington, including Puget Sound; major rivers within the Columbia River Basin in Idaho, Oregon, Washington, and Montana; and the St. Mary-Belly River, east of the Continental Divide in northwestern Montana (Cavender 1978a, Cavender 1978b, Bond 1992, Brewin and Brewin 1997, Brewin 1997, Leary and Allendorf 1997).

3.1.3.2 Critical Habitat

A final ruling on critical habitat for bull trout in the coterminous US was made on October 18, 2010 (effective November 17, 2010) (75 FR 63898). Critical habitat for bull trout includes approximately 32,187 km (20,000 mi.) of riverine habitat, 1,207 km (750 mi.) of marine shoreline, and 197,487 ha (488,001 ac) of lacustrine habitat. Critical habitat spans Washington, Oregon, Idaho, Nevada, and Montana (Figure 3-4).

The PBFs determined to be essential to the conservation of bull trout are:

- Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia;
- Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers;
- An abundance of food, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish;
- Complex shorelines with features such as large woody debris, side channels, pools, undercut banks, and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure;
- Water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures that exceed the upper end of this range;
- Sufficient and appropriate substrate in spawning and rearing areas;
- Water flows approximating natural timing (historic and seasonal ranges) for peak, high, low, and base flow;
- Sufficient water quality and quantity to sustain normal reproduction, growth, and survival; and
- Low occurrence of nonnative predatory (e.g., lake trout, walleye, northern pike, smallmouth bass), interbreeding (e.g., brook trout), or competing (e.g., brown trout) species.



Source: 75 FR 63898

Figure 3-4. Critical Habitat Units for Bull Trout of the Coterminous US.

3.1.3.3 Life History

Bull trout exhibit both resident and migratory life history strategies. Both resident and migratory forms may be found together, and either form may produce offspring exhibiting either resident or migratory behavior (Rieman and McIntyre 1993). Resident bull trout complete their entire life cycle in or near tributary streams where they spawn and rear. Migratory bull trout spawn in tributary streams where juvenile fish rear for one to four years before migrating to a lake, river (Fraley and Shepard 1989) (Goetz 1989), or saltwater (Cavender 1978b, McPhail and Baxter 1996); (WDFW 1997). Bull trout reach sexual maturity in four to seven years and may live longer than 12 years. They are iteroparous, meaning that they may spawn more than once in a lifetime. Bull trout typically spawn from August through November during periods of increasing flows and decreasing water temperatures. Spawning areas are often associated with cold-water springs, groundwater infiltration, and the coldest streams in a given watershed (Pratt 1992, Rieman and McIntyre 1993, Baxter et al. 1997, Rieman et al. 1997). Fry normally emerge from early April through May, depending on water temperatures and increasing stream flows (Ratlifratf and Howell 1992 in Howell and Buchanan 1992; Pratt 1992). Bull trout are primarily found in colder streams (below 15°C; 59°F) (Fraley and Shepard 1989; Pratt 1992; Rieman and McIntyre 1993), though they may be found in warmer waters that have access to colder refuges.

Bull trout have more specific habitat requirements than most other salmonids (Rieman and McIntyre 1993). Habitat components that influence bull trout distribution and abundance include water temperature (as described above), availability of cover, channel form and stability, valley form, spawning and rearing substrate, and migratory corridors (Fraley and Shepard 1989; Goetz 1989; Howell and Buchanan 1992; Pratt 1992; Rich 1996; Rieman and McIntyre 1993; Rieman and McIntyre 1995; Sedell and Everest 1991; Watson and Hillman 1997). All life history stages of bull trout are associated with complex forms of cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989; Goetz 1989; Hoelscher and Bjornn 1989; Pratt 1992; Rich 1996; Sedell and Everest 1991; Sexauer and James 1997; Thomas 1992; Watson and Hillman 1997). Early life stages of bull trout, specifically the developing embryo, require the highest inter-gravel dissolved oxygen levels, and are the most sensitive life stage to reduced oxygen levels. The oxygen demand of embryos depends on temperature and stage of development, with the greatest dissolved oxygen required just prior to hatching.

Bull trout are opportunistic feeders, with food habits primarily a function of size and life-history strategy. Resident and juvenile migratory bull trout prey on terrestrial and aquatic insects, macrozooplankton, and small fish (Boag 1987; Donald and Alger 1993; Goetz 1989). Bull trout may also feed heavily on fish eggs of other salmon (Lowery and Beauchamp 2015). Subadult and adult migratory bull trout feed on various fish species (Brown 1994; Donald and Alger 1993; Fraley and Shepard 1989; Leathe and Graham 1982). In marine nearshore areas of western Washington, bull trout feed on Pacific herring, Pacific sand lance, and surf smelt (Goetz et al. 2004; WDFW et al. 1997). Bull trout of sizes greater than fry have been found to eat fish up to half their length (Beauchamp and VanTassell 2001).

3.1.3.4 Current Stressors and Threats

Throughout their range, bull trout are threatened by the combined effects of habitat degradation, fragmentation, and alterations associated with dewatering, road construction and maintenance, mining, grazing, the blockage of migratory corridors by dams or other diversion structures, entrainment in diversion channels, and introduced non-native species (64 FR 58910). Although all salmonids are likely to be affected by climate change, bull trout are especially vulnerable given that spawning and rearing are constrained by their location in upper watersheds and the requirement for cold water temperatures (Battin et al. 2007; Rieman et al. 2007). Additional threats to bull trout include industrial development and urbanization, timber harvest, and poaching or bycatch.

The iteroparous reproductive strategy of bull trout has important repercussions for the management of this species. Bull trout require passage both upstream and downstream for both spawning and foraging, and passage must be allowed for multiple spawning migrations. However, most fish ladders were designed specifically for anadromous, semelparous salmonids (spawning once before death). Therefore, fish passage facilities (e.g., fish ladders) at barriers to migration may be a factor in isolating bull trout populations because they do not provide downstream passage for adults and subadults. Additionally, in some core areas, bull trout that migrate to marine waters must pass both upstream and downstream through areas with net fisheries at river mouths. This can increase the likelihood of mortality during spawning and foraging migrations.

Climate change is likely to play an increasingly important role in determining the abundance of ESA-listed species and the conservation value of designated critical habitats in the Pacific Northwest. Average regional temperatures are likely to increase by 3°F to 10°F over the next century (USGCRP 2009). Overall, about one-third of the current cold-water habitat in the Pacific Northwest is likely to exceed water temperature thresholds for bull trout by the end of this century (USGCRP 2009). Significant reductions in both total snowpack and low-elevation snowpack in the Pacific Northwest are predicted over the next 50 years (Mote and Salathé 2010), which will shrink the extent of the snowmelt-dominated habitat available to salmonids and cause warmer temperatures after snowmelt has run off (USGCRP 2009). As the snow pack diminishes and seasonal hydrology shifts to more frequent and severe early large storms, stream flow timing and increased peak river flows may limit salmonid survival (Mantua et al. 2010). Similarly, marine conditions adverse to salmonids may be more likely under a warming climate (Zabel et al. 2006).

3.2 Species Managed by the National Marine Fisheries Service

Table 3-1. Salmon and steelhead physical and biological features (PBFs) of critical habitats and corresponding species life history events

PBFs for chum, coho, Chinook salmon, and sockeye salmon		
Site	**Site Attribute**	**Species Life History Event**
Spawning and juvenile rearing areas	Access (sockeye) Cover/shelter Food (juvenile rearing) Riparian vegetation Space (Chinook) Spawning gravel Water quality Water temperature (sockeye) Water quantity	Adult spawning Embryo incubation Alevin development Fry emergence Fry/parr growth and development Fry/parr smoltification Smolt growth and development
Juvenile migration corridors	Cover/shelter Food Riparian vegetation Safe passage Space Substrate Water quality Water quantity Water temperature Water velocity	Fry/parr seaward migration Smolt growth and development Smolt seaward migration
Adult migration corridors	Cover/shelter Riparian vegetation Safe passage Space Substrate Water quality Water quantity Water temperature Water velocity	Adult sexual maturation Adult “reverse smoltification” Adult upstream migration Kelt (steelhead) seaward migration
PBFs for steelhead		
Freshwater spawning	Spawning gravel /substrate Water quality Water quantity	Adult spawning Embryo incubation Alevin development

PBFs for chum, coho, Chinook salmon, and sockeye salmon		
Site	**Site Attribute**	**Species Life History Event**
Freshwater rearing	Flood plain connectivity Forage Natural cover Water quality Water quantity	Fry emergence Fry/parr growth and development
Freshwater migration	Free of artificial obstructions Natural cover Water quality Water quantity	Adult sexual maturation Adult upstream migration Kelt (steelhead) seaward migration Fry/parr seaward migration

3.2.1 Chinook Salmon (*Oncorhynchus tshawytscha*)

Chinook salmon, also called king salmon, are the largest and least abundant species of Pacific salmon (NMFS 2005). Chinook salmon are anadromous, requiring both freshwater and saltwater to complete their life cycle. Juveniles generally spend three months to two years in freshwater before migrating to estuarine waters and eventually to sea, where they spend one to six years. Adults spend most of their lives in the ocean before migrating back to natal freshwater streams to spawn and then die. Compared to other Pacific salmon species, Chinook prefer larger and deeper stream habitat (NMFS 2005). Juveniles feed on terrestrial and aquatic invertebrates, while subadults (i.e., post-smolt stage) and adults consume larger prey such as shrimp, squid, small fish (e.g., herring [*Clupea* spp.] and sand lance [*Ammodytidae* spp.]) (Scott and Crossman 1973b). The distribution of Chinook salmon in the marine environment is not well characterized; however, they may be found as far north as Alaska, as far south as California, and as far west as Russia and Japan (NMFS 2016d).

NOAA Fisheries recognizes six ESA-listed ESUs of Chinook salmon that spawn in Washington, Oregon, and Idaho: two Snake River ESUs were listed in April 1992 (57 [FR] 14653); the Upper Willamette River (UWR) ESU was listed in March 1999 (64 FR 14308); and the two Columbia River ESUs and a single Puget Sound ESU were listed in August 1999 (64 FR 41835). In 2005, NOAA published a scientific report entitled *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*, which includes an updated status of Chinook salmon (Good et al. 2005). The five-year status review completed in 2010 (76 FR 50448) concluded that all Chinook salmon ESUs should remain listed. Each ESU is treated as a separate species under the ESA (76 FR 50448). ESUs may include both naturally spawned and artificially propagated (hatchery stock) fish.

3.2.1.1 Puget Sound Chinook Salmon ESU

The Puget Sound Chinook salmon ESU was listed as threatened on March 24, 1999 (64 FR 14308) and June 28, 2005 (70 FR 37159); updated April 14, 2014 (79 FR 20802). The Puget Sound Chinook salmon ESU includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan De Fuca (east of the

Elwha River), the Strait of Georgia (in Washington), and rivers and streams flowing into Hood Canal, South Sound, and North Sound. Additionally, all naturally spawned progeny of the 26 artificial propagation programs are considered part of this ESU (64 FR 14308).

3.2.1.1.1 Distribution

As noted above, Puget Sound Chinook salmon can be found in freshwater environments draining to the Puget Sound. Alterations to stream morphology and hydrology (e.g., construction of hydroelectric dams) has reduced salmon habitat in the Puget Sound region by limiting upstream migration to historical spawning habitats.

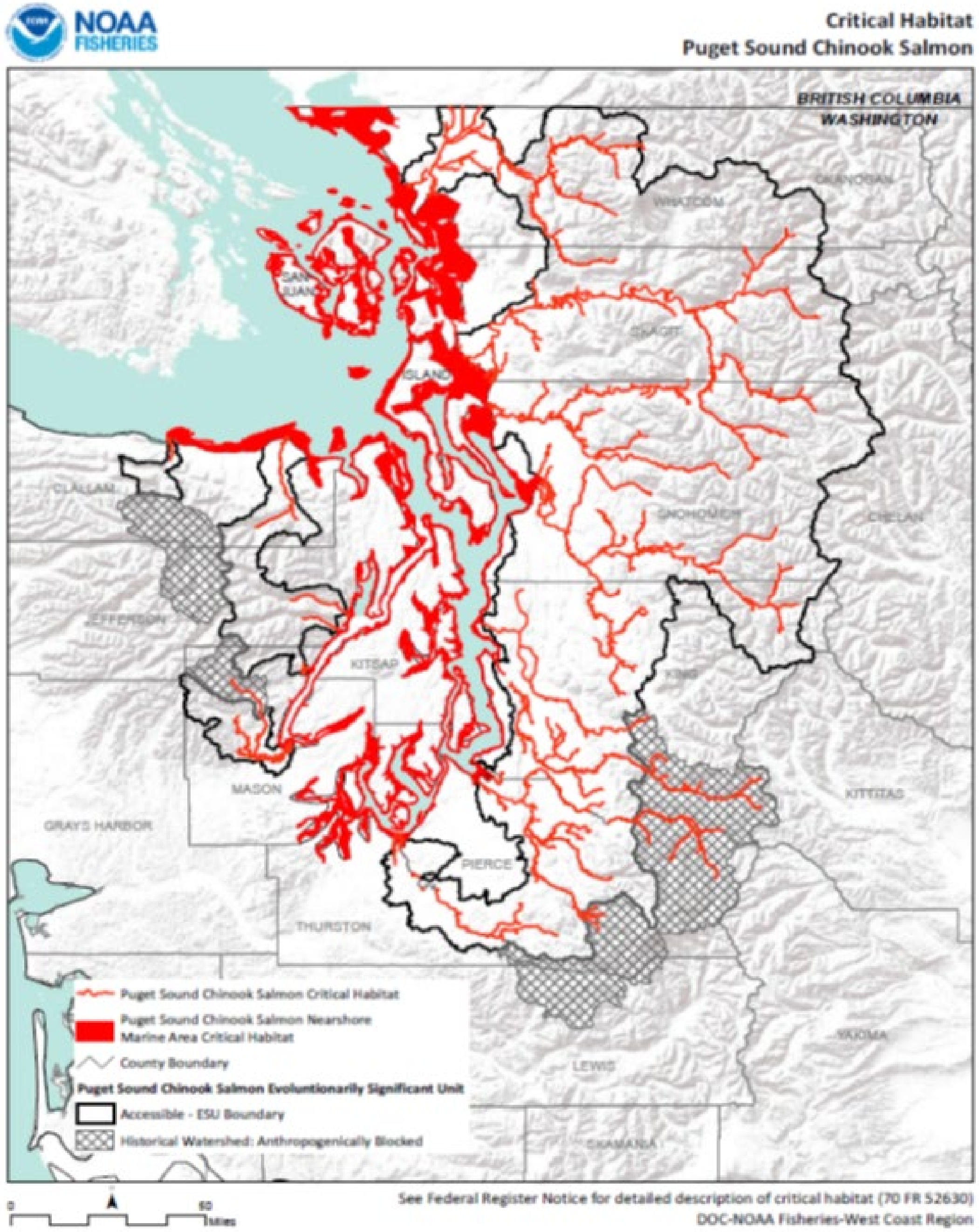
Although the exact distributions and migrations of Pacific Ocean salmon are currently not well understood, Puget Sound Chinook salmon fitted with coded tags appear to have common marine distributions, and they are mostly captured within Puget Sound and coastal Canadian waters (Weitkamp 2010). Individual salmon from the Puget Sound may migrate as far north as Alaska and as far west as Russia and Japan (NMFS 2016d).

3.2.1.1.2 Critical Habitat

Critical habitat for this ESU was designated in 2005 (70 FR 52630) (Figure 3-5). Critical habitat for the species includes all waters noted above (i.e., draining into Puget Sound) in which Chinook salmon rear and naturally spawn or are planted (by hatcheries).

The following PBFs apply to most West Coast salmon species (PBFs are noted in later sections, as applicable):

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development;
- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks;
- Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival;
- Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh water and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation;
- Nearshore marine areas free of obstruction, with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, that support growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and
- Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.



Source: (NOAA Fisheries 2016g)

Note: Chinook salmon habitat within the Elwha River watershed (gray hatch spanning Clallam and Jefferson Counties) has been reopened now that the Elwha and Glines Canyon Dams have been removed. The map predates the change to the watershed.

Figure 3-5. Critical Habitat for Puget Sound Chinook Salmon.

3.2.1.1.3 Life History

Chinook salmon exhibit consistent seasonal immigration patterns, with groups "running" (i.e., returning to freshwater streams) during spring, early summer, or early fall. Typically, spring-run Puget Sound Chinook salmon return to freshwater between April and May and spawn between August and September (Orrell 1976 as cited in Washington Department of Fisheries et al. 1993, Myers et al. 1998). Pre-spawn adults migrate upstream into pools, where they physiologically mature in preparation for spawning. Summer-run fish return to freshwater streams between June and July and spawn in September. Fall-run Chinook salmon return in August and spawn between late September and January (Washington Department of Fisheries et al. 1993). Within a single river, spawning times of different seasonal runs may overlap, but geographic separation within the river maintains some amount of reproductive isolation between runs (Myers et al. 1998).

Most Puget Sound Chinook salmon migrate to the sea as young-of-year juveniles,[1] where they often reside in estuaries that provide important nursery habitat for smolting juveniles.[2] The Suiattle and South Fork Nooksack Rivers are notable exceptions because migrating fish are predominantly yearlings (i.e., greater than or equal to one year but less than two years old) (Marshall et al. 1995 as cited in NOAA 2006). In these rivers, reduced smolting and production, delayed growth, and increased age of returning adults (i.e., at four to five years rather than three to four years) may be caused by an excess of glacial till.

3.2.1.1.4 Current Stressors and Threats

Limiting factors for Puget Sound Chinook salmon include degraded floodplain and in-river channel structure, degraded estuarine conditions and loss of estuarine habitat, degradation of riparian habitat and loss of in-river large woody debris, excessive fine-grained sediment in spawning gravels, degraded water quality (including dissolved oxygen) and temperature (i.e., increased temperatures), degraded nearshore conditions, impaired passage for migrating fish, and severely altered flow regimes. Other stressors include commercial and recreational harvest or bycatch (accidental) and predation (e.g., by killer whale).

3.2.1.2 Snake River Fall-Run Chinook Salmon

The Snake River fall-run Chinook salmon ESU was listed as threatened on April 22, 1992 (57 FR 14653), and the threatened status was reaffirmed in 2005 (70 FR 37160).

3.2.1.2.1 Distribution

The Snake River fall-run Chinook salmon ESU occupies the Snake River basin, which drains portions of southeastern Washington, northeastern Oregon, and north/ central Idaho. The Snake River fall-run Chinook salmon ESU includes one extant population of fish spawning in the mainstem of the Snake River and the lower reaches of several major tributaries, including the Tucannon, Grande Ronde, Clearwater, Salmon, and Imnaha Rivers. The ESU also includes four

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[1] "Young of year" is a term used to describe individuals of age less than one year.

[2] Smolting is a physiological change that allows anadromous salmon to move from freshwater to saltwater environments.

artificial propagation programs: the Lyons Ferry Hatchery and the Fall Chinook Acclimation Ponds Program in Washington; the Nez Perce Tribal Hatchery in Idaho; and the Oxbow Hatchery in Oregon (70 FR 37160). Historically, this ESU also included a large population that spawned in the mainstem of the Snake River upstream of the Hells Canyon Dam complex, which is currently an impassable barrier to migration (NOAA Fisheries 2015a).

3.2.1.2.2 Critical Habitat

Critical habitat for Snake River fall-run Chinook salmon was designated in 1993 and includes reaches of the Columbia, Snake, and Salmon Rivers and passable tributaries of the Snake and Salmon Rivers (58 FR 68543). The geographic extent of critical habitat is the Snake River to Hells Canyon Dam; Palouse River from its confluence with the Snake River upstream to Palouse Falls; Clearwater River from its confluence with the Snake River upstream to Lolo Creek; North Fork Clearwater River from its confluence with the Clearwater River upstream to Dworshak Dam; and all other river reaches presently or historically accessible within the Lower Clearwater, Hells Canyon, Imnaha, Lower Grande Ronde, Lower Salmon, Lower Snake, Lower Snake–Asotin, Lower North Fork Clearwater, Palouse, and Lower Snake–Tucannon sub-basins.

The PBFs for Snake River fall-run Chinook salmon are described in Table 3-2.

Table 3-2. Physical and Biological Features of Snake River Chinook Salmon Critical Habitat

Site	Physical and Biological Feature
Adult spawning and juvenile rearing	Suitable spawning gravel, water quality and quantity, water temperature, and access to spawning areas
Migration (adult and juvenile)	Suitable substrate, water quality and quantity, water temperature, water velocity, cover/shelter, food,[a] riparian vegetation, space, and safe passage

Note:
[a] Food applies to juvenile migration only.

3.2.1.2.3 Life History

Snake River fall Chinook salmon enter the Columbia River in July and August, and migrate past the lower Snake River mainstem dams from August through November. Spawning takes place from October through early December in the mainstem of the Snake River, primarily between Asotin Creek and Hells Canyon Dam, and in the lower reaches of several of the associated major tributaries, including the Tucannon, Grande Ronde, Clearwater, Salmon, and Imnaha Rivers (Connor and Burge 2003, Ford et al. 2011). Spawning has occasionally been observed in the tailrace areas of the four mainstem dams (Dauble et al. 1994, Dauble et al. 1995, Dauble et al. 1999, Mueller 2009). Juveniles emerge from the gravels in March and April of the following year.

Until relatively recently, Snake River fall Chinook were assumed to follow an "ocean-type" life history (Healey 1991, Dauble and Geist 2000, Good et al. 2005) (57 FR 14658), where they migrate to the Pacific Ocean during their first year of life, normally within three months of emergence from spawning substrate (as young-of-year smolts), to spend their first winter in the ocean. Ocean-type Chinook salmon juveniles tend to display a “rear as they go” strategy in which they continually move downstream through shallow shoreline habitats during the first summer and fall until they reach the ocean by winter (Connor and Burge 2003, Coutant and Whitney 2006). However, a substantial number of Snake River fall Chinook juvenile exhibit a “reservoir-type” life history, in which they begin their seaward migration later than ocean-types, arrest their migration and overwinter in reservoirs on the Snake and Columbia Rivers, then resume migration, entering the ocean in early spring as age-1 smolts (Connor et al. 2002, Connor and Burge 2003, Connor et al. 2005, Hegg et al. 2013). Analysis of fish scales taken from non-hatchery, adult, fall-run Chinook salmon indicate that approximately half of the returns passing Lower Granite Dam are reservoir type Snake River fall Chinook and overwintered in freshwater (Ford et al. 2011). Tiffan and Connor (2012) showed that young-of-year fish favor water less than 1.8 m (6 ft) deep.

3.2.1.2.4 Current Stressors and Threats

Stressors to Snake River Chinook salmon include commercial and recreational harvest, bycatch, and natural predation; reduced habitat and prey quality and quantity; and impeded migration pathways.

Spawning and rearing habitat quality in tributary streams in the Snake River varies from excellent in wilderness and roadless areas to poor in areas subject to intensive human land uses (NOAA Fisheries 2015a). Critical habitat throughout much of the Interior Columbia (which includes the Snake River and the Middle Columbia River; MCR) has been degraded by intensive agriculture, alteration of stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer streamflows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in non-wilderness areas. Human land use practices throughout the basin have caused streams to become straighter, wider, and shallower, thereby reducing rearing habitat and increasing water temperature fluctuations.

In many stream reaches designated as critical habitat in the Snake River basin, streamflows are substantially reduced by water diversions (NOAA Fisheries 2015a). Withdrawal of water, particularly during low-flow periods that commonly overlap with agricultural withdrawals, often increases summer stream temperatures, blocks fish migration, strands fish, and alters sediment transport (Spence et al. 1996).

Many stream reaches designated as critical habitat in the Snake River basin are on the CWA 303(d) list for impaired water quality (e.g., due to elevated water temperature) (IDEQ 2011). Many areas that were historically suitable rearing and spawning habitat are now unsuitable due to high summer stream temperatures, such as some stream reaches in the Upper Grande Ronde. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water for agricultural or municipal use all contribute to elevated stream temperatures. Water quality in spawning and rearing areas in the Snake River has also been impaired by high levels of sedimentation and by metal contamination potentially from mine waste (IDEQ 2001, IDEQ and EPA 2003).

Migration habitat quality for Snake River salmon has also been severely degraded, primarily by the development and operation of dams and reservoirs on the mainstem Columbia and Snake Rivers (NMFS 2008b). Hydroelectric development has modified natural flow regimes in the migration corridor, causing higher water temperatures and changes in fish community structure that have led to increased rates of piscivorous and avian predation on juvenile salmon, and delayed migration for both adult and juveniles. Physical features of dams, such as turbines, also kill migrating fish.

3.2.1.3 Snake River Spring/Summer-Run Chinook Salmon

The Snake River spring/summer-run Chinook salmon ESU was listed as threatened on April 22, 1992 (57 FR 14653), and the threatened status was reaffirmed in 2005 (70 FR 37160). The spring/summer run and fall run subpopulations are distinguished from one another by the seasons during which they return to freshwater streams.

3.2.1.3.1 Distribution

Snake River Chinook salmon occupy the Snake River basin in southeastern Washington, northeastern Oregon, and north/central Idaho. The Snake River ESU includes all naturally spawning populations of spring/summer-run Chinook in the mainstem Snake River (below Hells Canyon Dam) and in the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River sub-basins (57 FR 23458), as well as the progeny of 15 artificial propagation programs (70 FR 37160). The historical Snake River ESU likely also included populations in the Clearwater River drainage and extended above the Hells Canyon Dam complex; however, current runs returning to the Clearwater River drainages are not considered to be a part of the Snake River spring/summer-run Chinook salmon ESU.

3.2.1.3.2 Critical Habitat

Critical habitat for Snake River spring/summer-run Chinook salmon was designated in 1993 and 1999 and includes reaches of the Columbia, Snake, and Salmon Rivers and accessible tributaries of the Snake and Salmon Rivers (58 FR 68543 and 64 FR 57399). The geographic extent of critical habitat includes all Snake River reaches upstream to Hells Canyon Dam; all river reaches presently or historically accessible to Snake River spring/summer Chinook salmon within the Salmon River basin; and all river reaches presently or historically accessible to Snake River spring/summer Chinook salmon within the Hells Canyon, Imnaha, Lower Grande Ronde, Upper Grande Ronde, Lower Snake-Asotin, Lower Snake-Tucannon, and Wallowa sub-basins.

The PBFs for Snake River Chinook salmon (spring/summer and fall runs) are provided in Table 3-2.

3.2.1.3.3 Life History

Snake River spring/summer Chinook salmon are characterized by their return times. Spring runs are counted at Bonneville Dam beginning in early March and ending the first week of June. Summer runs include Chinook adults that pass Bonneville Dam from June through August. Returning adults will hold migration in deep mainstem and tributary pools until late summer, when they move up into tributary areas to spawn. In general, spring-run Chinook salmon tend to spawn in higher-elevation reaches of major Snake River tributaries in mid- to late August, and summer-run Chinook salmon tend to spawn lower in Snake River tributaries in late August and September. The spawning areas of the two runs may overlap.

Spring/summer Chinook follow a "stream-type" life history characterized by rearing for a full year in spawning habitat before migrating to the sea (Healey 1991). Eggs are deposited in late summer and early fall, incubate through the winter, and hatch between late winter and early spring. Juveniles rear through the summer, and most overwinter and migrate to the sea in the spring of their second year. Depending on the tributary and the specific habitat conditions, juveniles may migrate extensively from natal reaches into alternative summer-rearing or overwintering areas. Snake River spring/summer Chinook salmon return from the ocean to spawn primarily as four- and five-year-old fish, after two to three years in the ocean. A small fraction of the fish return as three-year old "jacks" (precocious spawners), of which the majority are males (Good et al. 2005).

3.2.1.3.4 Current Stressors and Threats

Limiting factors for Snake River spring/summer run Chinook salmon are the same as those listed above for the Snake River fall-run Chinook salmon subpopulation.

3.2.1.4 Upper Columbia River Spring-Run Chinook Salmon

On March 24, 1999, NMFS listed the Upper Columbia River (UCR) spring-run Chinook salmon as an endangered species (64 FR 14308). The status of this ESU was reaffirmed on June 28, 2005 (70 FR 37160) and again on August 15, 2011, after the five-year status review (76 FR 50448).

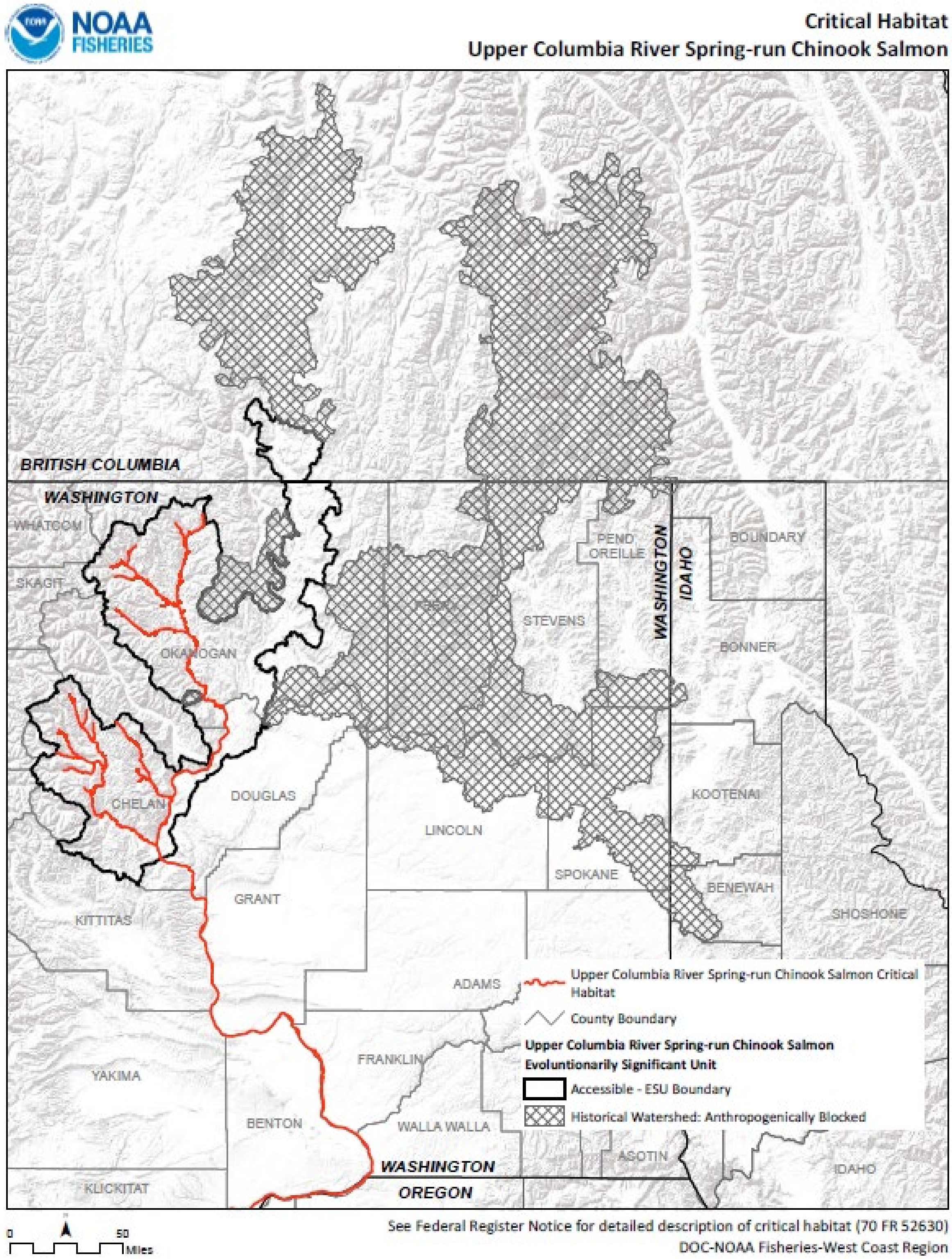
3.2.1.4.1 Distribution

The ESU includes all naturally spawned populations of Chinook salmon in all river reaches accessible to Chinook salmon in the Columbia River tributaries upstream of Rock Island Dam and downstream of Chief Joseph Dam (barrier to upstream movement), excluding the Okanogan River (64 FR 14208). Six artificial propagation programs are included in this ESU: The Twisp River, Chewuch River, Methow Composite, Winthrop National Fish Hatchery, Chiwawa River, and White River spring-run Chinook hatchery programs.

3.2.1.4.2 Critical Habitat

Critical habitat for UCR Chinook salmon was designated for Oregon and Washington in 2005 and includes freshwater areas shown in Figure 3-6 (70 FR 52630).

The PBFs for UCR Chinook salmon are the same as those described above for Puget Sound Chinook salmon.



Source: (NOAA Fisheries 2016i)

Figure 3-6. Critical Habitat for Upper Columbia River Spring-run Chinook Salmon.

3.2.1.4.3 Life History

UCR spring-run Chinook salmon exhibit stream-type life history strategies. Adults begin returning from the ocean in the early spring, with the run into the Columbia River peaking in mid-May. They then enter UCR tributaries from April through July, where they hold until spawning occurs in the late summer, peaking in mid to late August. Juvenile spring-run Chinook salmon spend a year in freshwater before migrating to the ocean. Most UCR spring-run Chinook salmon return as adults after two or three years in the ocean.

3.2.1.4.4 Current Stressors and Threats

Limiting factors for UCR spring-run Chinook salmon include impacts from Columbia River hydropower (i.e., modified hydrograph and increase in lentic conditions/decrease in riverine conditions, passage barriers, temperature; dissolved oxygen problems, and invasive species), riparian degradation and reduced large wood recruitment, altered floodplain connectivity and function, altered channel structure and complexity, reduced streamflow, and hatchery-related impacts (e.g., reduced genetic diversity) (NMFS 2011a).

3.2.1.5 Lower Columbia River Chinook Salmon

The LCR Chinook salmon ESU was listed as threatened pursuant to 76 FR 50448, and this determination was reaffirmed in 2011.

3.2.1.5.1 Distribution

The LCR Chinook salmon ESU includes all naturally spawned Chinook salmon originating from the Columbia River and its tributaries downstream of a transitional point east of the Hood and White Salmon Rivers and any such fish originating from the Willamette River and its tributaries below Willamette Falls. Also, this ESU includes Chinook salmon from 15 artificial propagation programs (79 FR 20802). The following individuals are not included in the ESU:

- Spring-run Chinook salmon originating from the Clackamas River;
- Fall-run Chinook salmon originating from the UCR bright hatchery stocks that spawn in the mainstem Columbia River below Bonneville Dam or in other tributaries upstream from the Sandy River to the Hood and White Salmon Rivers;
- Spring-run Chinook salmon originating from the Round Butte Hatchery (Deschutes River, Oregon) and spawning in the Hood River;
- Spring-run Chinook salmon originating from the Carson National Fish Hatchery and spawning in the Wind River; and
- Naturally spawning Chinook salmon originating from the Rogue River Fall Chinook Program.

Dam removal projects have reopened historical habitat once blocked to migrating LCR Chinook salmon. The removal of Marmot Dam in the Sandy River eliminated migration delays and injuries associated with holding at the dam's fish ladder. Additionally, the removal of the diversion dam on the Little Sandy River restored access and flow to historical salmon habitat. The removal of Condit Dam on the White Salmon River provides an opportunity for the reestablishment of a spring-run population with renewed access to historical spawning grounds. Spring-run Chinook salmon in the Hood River are largely from the Deschutes River spring-run (managed under the MCR spring-run ESU) and are not considered to benefit the status of the LCR ESU. However, some LCR spring-run Chinook salmon have been detected in the Hood River (NWFSC 2015).

3.2.1.5.2 Critical Habitat

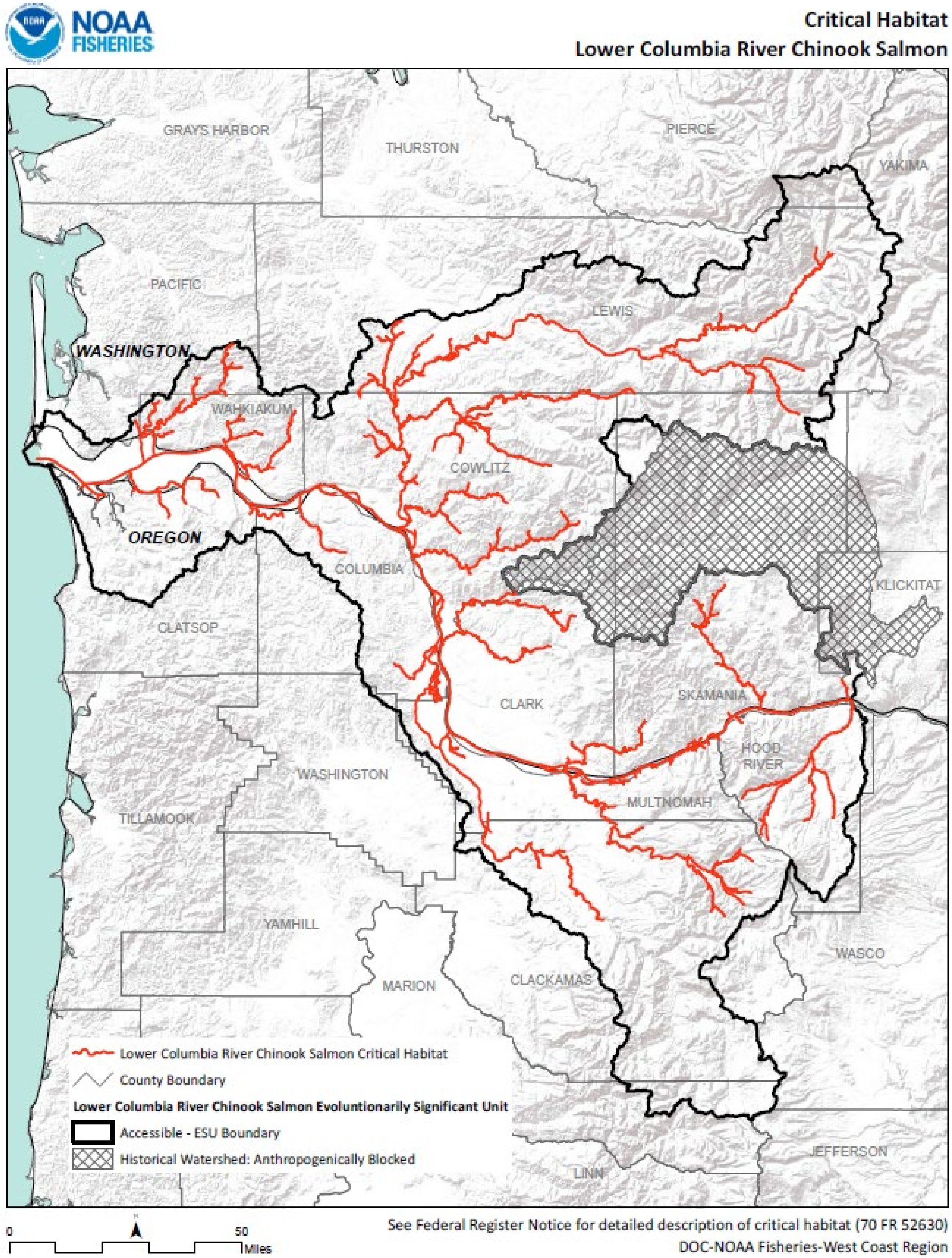
Critical habitat for LCR Chinook salmon was designated for Oregon and Washington in 2005 and includes watersheds shown in Figure 3-7 (70 FR 52630). The PBFs for LCR Chinook salmon are the same as those described above for Puget Sound Chinook salmon.

3.2.1.5.3 Life History

LCR Chinook salmon generally follow an ocean-type (fall-run) life history cycle. These salmon migrate to the ocean within the first year, after one to four months of rearing in freshwater habitat in the spring (NOAA Fisheries 2005). Chinook fry emerge in April and quickly find protection in off-stream refuge habitat. Some Chinook remain in their natal streams until the spring after hatching, at which point they emigrate as yearlings. Ocean-type Chinook return to the Columbia River at approximately three to four years of age. Entry to the Columbia River occurs generally from August to September; spawning begins in late September through November and peaks in mid-October (NOAA Fisheries 2005). Spawning occurs in the lower reaches of Columbia River tributaries (NOAA Fisheries 2005, NMFS 2013). There is also a subpopulation of fall-run LCR. The subpopulation of Chinook "brights" enter the Columbia River slightly later than the rest of the population, from August to October, and spawn from November to January. Peak bright spawning occurs in mid-November.

Spring-run or stream-type LCR Chinook spawn in August to September in Columbia River headwaters from the age of four to five years, a full year after returning to freshwater. Generally, the return of spring-run LCR Chinook occurs in March and April. Juvenile spring-run Chinook emerge from sediments between November and March with peak emergence occurring between December and January (NOAA Fisheries 2005).

There are 32 populations in the LCR Chinook salmon ESU: nine spring run, 21 fall run, and two late fall runs (named according to the seasonal return to streams).



Source: (NOAA Fisheries 2016c)

Figure 3-7. Critical Habitat for Lower Columbia River Chinook Salmon.

3.2.1.5.4 Current Stressors and Threats

Limiting factors for LCR Chinook salmon include relatively high harvest rates, especially for the spring-run, and low abundance of fall-run populations (NMFS 2012a); migratory impediment caused by dams (i.e., Mossyrock Dam on the Cowlitz River); land development and habitat degradation; and potential effects from climate change and coastal ocean conditions (e.g., reduced survival of emigrating smolts and corresponding drop in spawner abundance) (NWFSC 2015). Reduced complexity, connectivity, quantity, and quality of habitat used for spawning, rearing, foraging, and migrating are perhaps the most important limitations to LCR Chinook population growth. Degradation or loss of habitat due to conversion to agricultural or urbanized uses (e.g., diking and draining of wetlands and floodplain) is also of particular concern (Bottom et al. 2005, NMFS 2013). Reduced habitat complexity has resulted in a concomitant increase in water temperatures (ODFW 2010, NMFS 2013). Contamination of salmon habitat from wastewater treatment plant effluent, stormwater runoff, and nonpoint source pollution is a growing concern (Morace 2012, NMFS 2013, Nilsen and Morace 2014). Data collected by Ecology, Oregon Department of Environmental Quality (ODEQ), and the Columbia River Contaminants and Habitat Characterization Project indicate that contaminants are present above levels of concern (Counihan et al. 2013, Alvarez et al. 2014, Nilsen and Morace 2014).

3.2.2 Chum Salmon (*Oncorhynchus keta*)

Chum salmon are a species of anadromous salmonid that typically live for four years and grow to 6.8 kilograms (kg) (15 pounds) and can grow up to 1.1 m (3.6 ft) long (NMFS 2015a). They take on a characteristic greenish blue color that becomes striped with red slashes during spawning, and spawning adult males develop elongated “canine” teeth, which explains the colloquial name for this species, “dog salmon” (NMFS 2015a). Chum spawn once before dying in freshwater streams.

Juvenile chum salmon quickly migrate into the marine environment after hatching, where, unlike other salmonids, they congregate in schools (NMFS 2015a). The diet of chum salmon tends to shift from insects and other benthic invertebrates while in freshwater to crustaceans, fish, mollusks, squid, and tunicates while in the ocean (NMFS 2015a).

The distribution of chum salmon in the marine environment is not well understood; however, it appears that they migrate as far north as Alaska, as far south as California, and as far west as Russia and Japan (Beamish and Bouillon 1993).

3.2.2.1 Hood Canal Summer-run Chum Salmon

On June 28, 2005, NMFS listed Hood Canal summer-run (HCS) chum salmon as a threatened species (70 FR 37160). This ESU includes all non-hatchery and some hatchery-raised individuals (within the designated distribution of the ESU).

3.2.2.1.1 Distribution

The HCS chum salmon ESU comprises all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries, as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington. Four artificial propagation programs were listed as part of the ESU (79 FR 20802): the Hamma Fish Hatchery Program, Lilliwaup Creek Fish Hatchery Program, Tahuya River Program, and Jimmycomelately Creek Fish Hatchery Program.

The HCS chum salmon ESU has two populations (Strait of Juan de Fuca and Hood Canal populations), each containing multiple stocks or spawning aggregations. In the Strait of Juan de Fuca population, there are small but persistent natural spawning aggregations in three streams: Salmon, Snow, and Jimmycomelately Creeks. In the Dungeness River, spawning occurs but the aggregation of spawners is not known. In Chimacum Creek, HCS chum salmon were extirpated in the mid-1980s. Spawning aggregations have persisted in most of the major rivers draining from the Olympic Mountains into the western edge of Hood Canal, including Big Quilcene, Little Quilcene, Dosewallips, Duckabush, and Hamma Rivers and Lilliwaup Creek. On the eastern side of Hood Canal, persistent spawning is restricted to the Union River (Sands et al. 2009). Based on river size and historical tribal fishing records, a major spawning aggregation once occurred in the Skokomish River before the construction of Cushman Dam in the 1920s. State and tribal biologists also identified recent extinctions in Big Beef Creek, Anderson Creek, Dewatto River, Tahuya River, and Finch Creek. Historically, streams including but not limited to Seabeck, Stavis, Big Mission, and Little Mission Creek probably supported summer-run chum salmon.

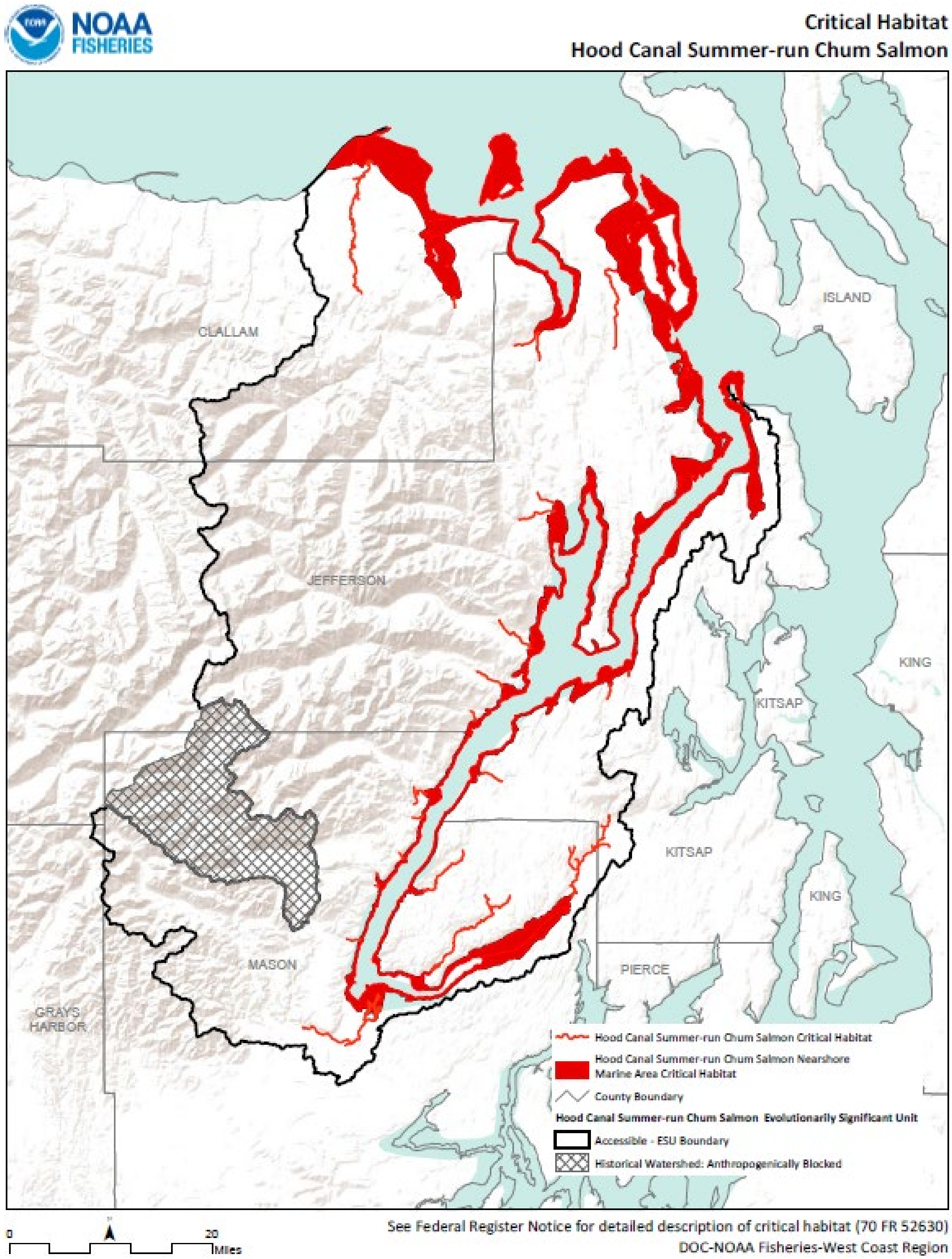
3.2.2.1.2 Critical Habitat

Critical habitat for HCS chum salmon was designated for Washington in 2005 and includes freshwater, estuarine, and marine areas shown in Figure 3-8 (70 FR 52630). There are approximately 127 km (79 miles) of stream habitats and 607 km (377 miles) of nearshore marine habitats designated as critical habitat. The PBFs for HCS chum salmon are the same as those described above for Puget Sound Chinook salmon.

3.2.2.1.3 Life History

HCS chum salmon return to freshwater during summer. Juveniles, typically as fry, emerge from the gravel and emigrate almost immediately to seawater, indicative of an ocean-type life strategy. Upon reaching saltwater, HCS chum salmon spend several weeks in the top 2 to 3 cm (0.79 to 1.18 inches) of estuarine surface waters very close to the shoreline (WDFW and PNPTT 2000). Subadults and adults forage in coastal and offshore waters of the North Pacific Ocean before returning to spawn in their natal streams at age three to five. HCS chum salmon spawn from mid-September to mid-October, typically in river mainstems and lower river basins.

HCS chum salmon ESU fecundity estimates average 2,500 eggs per female, and the proportion of female spawners is approximately 45% of escapement in most populations (WDFW and PNPTT 2000).



Source: (NOAA Fisheries 2016b)

Figure 3-8. Critical Habitat for Hood Canal Summer-run Chum Salmon.

3.2.2.1.4 Current Stressors and Threats

Limiting factors for the HCS chum salmon ESU include degraded habitat, barriers to migration, and changes to the salmon prey base. More specifically, limitations on habitat are caused by the degradation of water quality, loss of floodplain connectivity and function, loss of channel structure and complexity, loss of riparian habitat, reduced large woody debris recruitment, altered stream substrate (e.g., embeddedness by fine sediments), and altered stream flow (NMFS 2016a).

Human activities that affect the PBFs of critical habitat for HCS chum salmon include forestry; agriculture; road building/maintenance; channel modifications/diking; urbanization; sand and gravel mining; dams; river, estuary, and ocean traffic; and the removal of beavers. In addition to these, the harvest of salmonid prey species (e.g., herring, anchovy, and sardines) affects nearshore marine PBFs.

Stream channels and estuaries are, with few exceptions, moderately to highly degraded throughout the HCS chum salmon ESU. During the past 150 years, logging, road building, rural development, agriculture, water withdrawal, and channel manipulations (e.g., dredging and channelization) were common and widespread, especially within low gradient stream reaches utilized by HCS chum salmon. Three quarters of the HCS chum salmon ESU's watersheds contain simplified, degraded channels either completely lacking a forested riparian zone or surrounded by small diameter, deciduous-dominated forests. Most streams have degraded or reduced pool densities and insufficient large woody debris.

Development has occurred in nearly all estuaries within Hood Canal and the eastern Strait of Juan de Fuca. Dikes, roads or causeways, ditches, and fill are the primary causes of estuarine habitat degradation. In estuarine and nearshore areas, bulkheads, revetments, and impaired riparian corridors have reduced the amount of rearing habitat. Altered river and tidal dynamics have likely reduced estuarine food web productivity and, thus, the carrying capacity for chum salmon and other salmonids in the estuarine environment (NMFS 2016f).

3.2.2.2 Columbia River Chum Salmon

The Columbia River chum salmon ESU was listed as threatened March 25, 1999 (64 FR 14508), and this determination was reaffirmed in 2011.

3.2.2.2.1 Distribution

The Columbia River chum salmon ESU includes naturally spawned chum salmon originating from the Columbia River and its tributaries in Washington and Oregon. Also, the ESU includes chum salmon from two artificial propagation programs, the Grays River Program and the Washougal River Hatchery/Duncan Creek Program (79 FR 20802). The Columbia River chum salmon ESU consists of 17 historical populations in three major population groups (i.e., the Coastal, Cascade, and Gorge groups) (NMFS 2013).

3.2.2.2.2 Critical Habitat

Critical habitat for Columbia River chum salmon was designated for Oregon and Washington in 2005 and includes areas shown in Figure 3-9 (70 FR 52630). The PBFs for Columbia River chum salmon are the same as those described above for Puget Sound Chinook salmon.

3.2.2.2.3 Life History

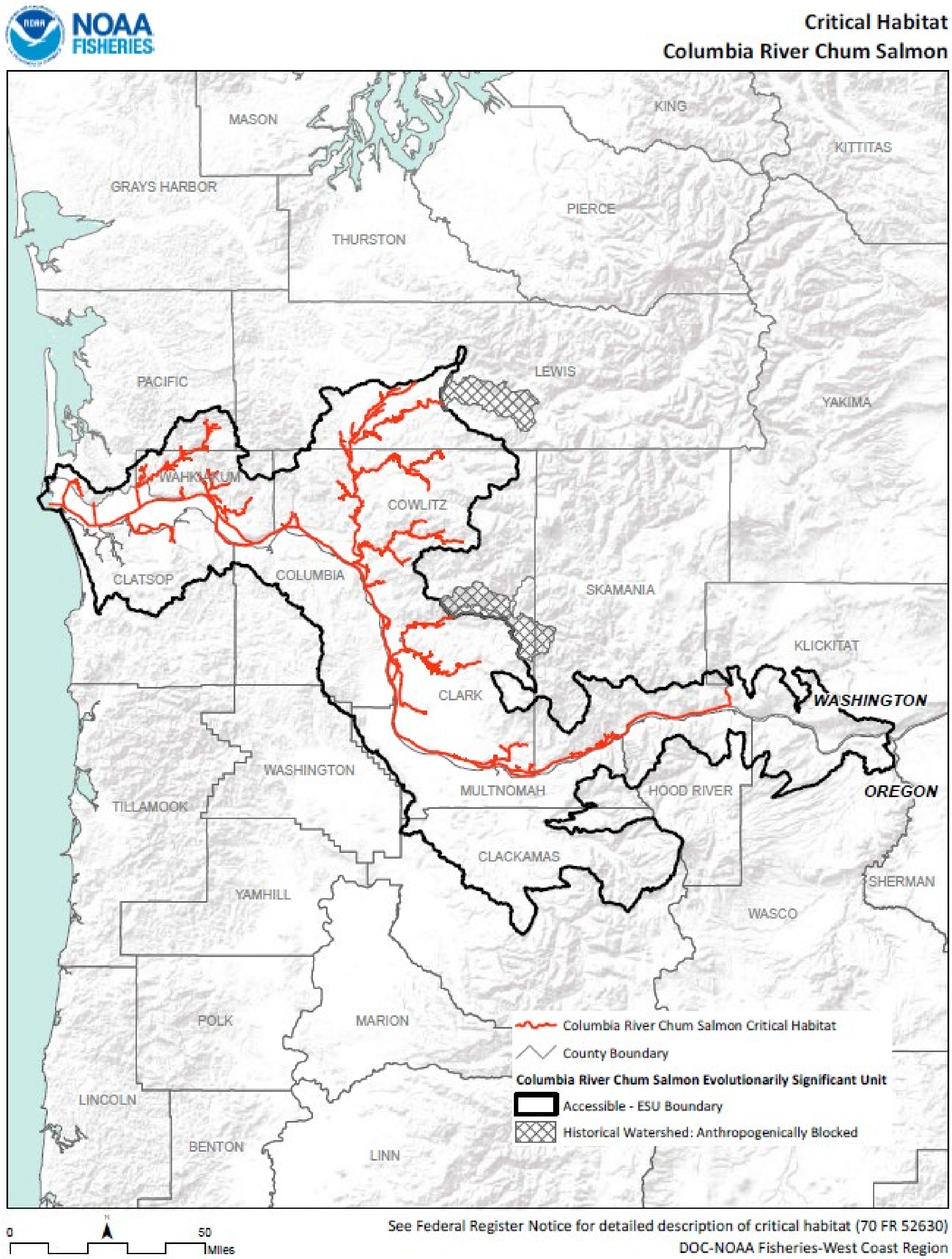
Columbia River chum salmon run in the fall, spawning in tributaries of the Columbia River below the Bonneville Dam (e.g., Grays River and Hardy and Hamilton Creeks) (NMFS 2015b). Columbia River Chum salmon fry emerge from spawning gravel and almost immediately drift downstream toward the ocean. Unlike other salmonids, Columbia River chum salmon do not have a distinct smolt life stage. As subadults and adults, Columbia River chum salmon feed in marine nearshore and open waters of the North Pacific Ocean. After three to five years, Columbia River chum salmon return to their natal streams to spawn, typically between mid-October and early December (spawning until mid-January) in the mainstem Columbia River or in the lower portions of tributaries.

3.2.2.2.4 Current Stressors and Threats

Limiting factors for Columbia River chum salmon include poor ocean conditions in the near future (e.g., reduced or altered food web due to climate change and acidification limiting of juvenile survival) (NWFSC 2015), reduced freshwater habitat quality (limiting of spawning and early rearing success in some basins), and land development, especially in the low gradient reaches that Columbia River chum salmon prefer. Based on projected increases in the population of the greater Vancouver-Portland area and the LCR overall (Metro 2014), land development is expected to continue to limit the recovery of most chum salmon populations.

3.2.3 Coho Salmon (*Oncorhynchus kisutch*)

Coho salmon adults migrate to and spawn in small streams that flow directly into the ocean, or tributaries and headwater creeks of larger rivers (Sandercock 1991, Moyle et al. 2002). Adults migrate upstream to spawning grounds from September through late December, peaking in October and November. Spawning occurs mainly November through December, with fry emerging from the gravel in the spring, approximately three to four months after spawning. Juvenile rearing usually occurs in tributary streams with a gradient of 3% or less, although they may move up to streams of 4% or 5% gradient. Juveniles have been found in streams as small as 1 to 2 m (3.3 to 6.6 ft) wide. They may spend one to two years rearing in freshwater (Bell and Duffy 2007) or emigrate to an estuary shortly after emerging from spawning gravels (Tschaplinski 1988). With the onset of fall rains, coho salmon juveniles are also known to redistribute into non-natal rearing streams, lakes, or ponds, where they overwinter (Peterson 1982). At a length of 38 to 45 mm (1.5 to 1.8 in), fry may migrate upstream a considerable distance to reach lakes or other rearing areas (Sandercock 1991, Nickelson et al. 1992). Emigration from streams to the estuary and ocean generally takes place from March through June. The marine distribution of coho salmon extends from Alaska to California and west to Russia and Japan (NMFS 2016e).



Source: (NOAA Fisheries 2016a)

Figure 3-9. Critical Habitat for Columbia River Chum Salmon.

3.2.3.1 Lower Columbia River Coho Salmon

The LCR coho salmon ESU was listed as threatened pursuant to (76 FR 50448), and this determination was reaffirmed in 2011.

3.2.3.1.1 Distribution

The LCR coho salmon ESU includes all naturally spawned coho salmon originating from the Columbia River and its tributaries downstream from the Big White Salmon and Hood Rivers (inclusive) and any such fish originating from the Willamette River and its tributaries below Willamette Falls. Also included in the ESU are coho salmon from 21 artificial propagation programs (79 FR 20802).

3.2.3.1.2 Critical Habitat

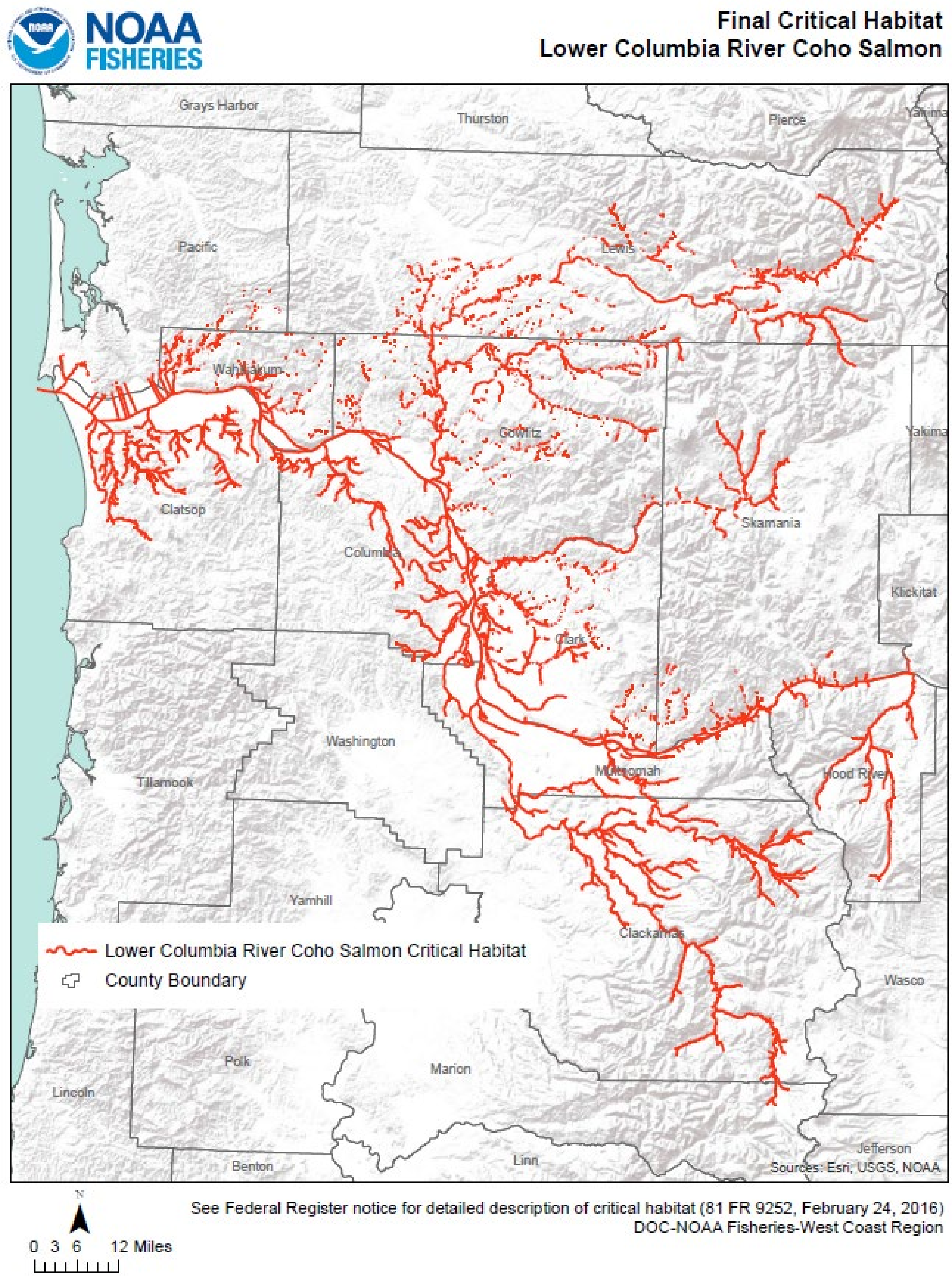
Critical habitat for LCR Coho salmon was designated for Oregon and Washington in 2016 and includes areas shown in Figure 3-10 (81 FR 9252). The PBFs for LCR coho salmon are the same as those described above for Puget Sound Chinook salmon.

3.2.3.1.3 Life History

Adults typically spend approximately 18 months in freshwater streams and 18 months in marine waters before returning to natal streams to spawn as three-year olds (NMFS 2015b). Two spawning groups have been identified, “type S” and “type N”; type S fish tend to enter rivers to spawn from mid-August to September and spawn in mid-October to early November, whereas type N fish enter rivers in late September to December and spawn between November and January (NMFS 2015b). Type S fish tend to spawn higher in tributaries of the Columbia River, whereas type N fish spawn in lower tributaries.

3.2.3.1.4 Current Stressors and Threats

Limiting factors for LCR coho salmon include migratory impediment caused by dams (i.e., sediment retention structure on the North Fork Toutle River) (Fullerton et al. 2011, NMFS 2013); land development and habitat degradation; and potential effects from climate change and coastal ocean conditions (e.g., reduced survival of emigrating smolts and corresponding drop in spawner abundance) (NWFSC 2015). Reduced complexity, connectivity, quantity, and quality of habitat used for spawning, rearing, foraging, and migrating are perhaps the most important limitations to LCR coho. Degradation or loss of habitat due to conversion to agricultural or urbanized uses (e.g., diking and draining of wetlands and floodplain), reduced complexity, and persistent inputs of wastewater, stormwater, and non-point-source runoff are key concerns (Bottom et al. 2005, ODFW 2010, Morace 2012, NMFS 2013, Nilsen and Morace 2014, NOAA Fisheries 2016q). Data collected by Ecology, ODEQ, and the Columbia River Contaminants and Habitat Characterization Project indicate that contaminants are present above levels of concern (Counihan et al. 2013, Alvarez et al. 2014, Nilsen and Morace 2014)) and that Total Maximum Daily Loads are warranted for the LCR.



Source: (NOAA Fisheries 2016k)

Figure 3-10. Critical Habitat for Lower Columbia River Coho Salmon.

3.2.4 Sockeye Salmon (*Oncorhynchus nerka*)

Sockeye salmon are the second most abundant of the seven Pacific salmon species (Quinn 2005). They display more life history diversity than all other members of the *Oncorhynchus* genus (Burgner 1991). Sockeye salmon are generally anadromous, but distinct populations of non-anadromous *O. nerka* also exist; these fish are commonly referred to as kokanee (*O. nerka kennerlyi*) or silver trout (Wydoski and Whitney 2003). The vast majority of sockeye populations spawn in or near lakes. Spawning can take place in lake tributaries, lake outlets, rivers between lakes, and on lake shorelines or beaches where suitable upwelling or intra-gravel flow is present. Spawn timing is often determined by water temperature. In spawning habitats with cooler water temperatures, sockeye typically spawn earlier (August) than in warmer habitats (November) (Burgner 1991). Sockeye fry that are spawned in lake tributaries typically exhibit a behavior of rapid downstream migration to the nursery lake after emergence, whereas lake/beach spawned sockeye rapidly migrate to open limnetic waters after emergence. Lake-rearing juveniles typically spend one to three years in their nursery lake before emigrating to the marine environment (Gustafson et al. 1997). Other life history variants include ocean-type and river-type sockeye. Ocean-type populations typically use large rivers and side channels or spring-fed tributary systems for spawning and emigrate to sea soon after emergence. River-type sockeye rear in rivers for one year before emigrating to sea. Quinn (2005) describes the differences between ocean-type and river-type sockeye as a continuum of rearing patterns rather than as two discrete types.

Upon smolting, sockeye emigrate to the ocean. Peak emigration occurs in mid-April to early May in southern sockeye populations (generally south of 52°N latitude) and as late as early July in northern populations (62°N latitude and north) (Burgner 1991). Typically, river-type sockeye populations make little use of estuaries during their emigration to the marine environment (Quinn 2005). Estuarine habitats may be more extensively used by ocean-type sockeye (Quinn 2005). Upon entering marine waters, sockeye may reside in the nearshore or coastal environment for several months but are typically distributed offshore by fall (Burgner 1991).

In the marine environment, North American sockeye stocks are limited to the zone north of 46°N latitude. Within these zones, sockeye salmon have a wide distribution. In North America, their range is south to the Sacramento River in California (historically) and as far north as Kotzebue Sound in Alaska. In the Western Pacific, sockeye can be found from the Kuril Islands of Japan to Cape Chaplina in Russia.

3.2.4.1 Snake River Sockeye Salmon

The Snake River sockeye salmon ESU was first listed as endangered under the ESA in 1991, and the listing was reaffirmed in 2005 (70 FR 37160). On May 26, 2016, in the most recent five-year review for Pacific salmon and steelhead, NMFS concluded that the species should remain listed as endangered (81 FR 33468).

3.2.4.1.1 Distribution

This ESU includes all anadromous and resident sockeye salmon from the Snake River basin in Idaho, as well as artificially propagated sockeye salmon from the Redfish Lake captive propagation program.

3.2.4.1.2 Critical Habitat

Critical habitat for Snake River sockeye salmon was designated in 1993 and includes the Snake and Salmon Rivers, Alturas Lake Creek, Valley Creek, Stanley Lake, Redfish Lake, Yellowbelly Lake, Pettit Lake, Alturas Lake, and all inlet/outlet creeks to the aforementioned lakes (58 FR 68543). PBFs for Snake River sockeye salmon critical habitat are described in Table 3-2.

3.2.4.1.3 Life History

Snake River sockeye salmon adults enter the Columbia River primarily during June and July and arrive in the Sawtooth Valley, peaking in August. The Sawtooth Valley supports the only remaining run of Snake River sockeye salmon. The adults spawn in lakeshore gravels, primarily in October (Bjornn and Reiser 1991). Eggs hatch in the spring between 80 and 140 days after spawning. Fry remain in gravels for three to five weeks, emerge from April through May and move immediately into lakes. Once there, juveniles feed on plankton for one to three years before they migrate to the ocean, leaving their natal lake in the spring from late April through May. Snake River sockeye salmon usually spend two to three years in the Pacific Ocean and return to Idaho in their fourth or fifth year of life.

3.2.4.1.4 Current Stressors and Threats

Spawning and rearing habitat quality in tributaries of the Snake River varies from excellent in wilderness areas to poor in areas of intensive human land uses (NOAA Fisheries 2015a). Critical habitat throughout much of the Interior Columbia (which includes the Snake River and the MCR) has been degraded by intensive agriculture, alteration of stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer streamflows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in non-wilderness areas. Human land use practices throughout the basin have caused streams to become straighter, wider, and shallower, thereby reducing rearing habitat and increasing water temperature fluctuations. In many stream reaches designated as critical habitat in the Snake River basin, streamflows are substantially reduced by water diversions (NOAA Fisheries 2015a). Withdrawal of water, particularly during low-flow periods that commonly overlap with agricultural withdrawals, often increases summer stream temperatures, blocks fish migration, strands fish, and alters sediment transport (Spence et al. 1996).

Many stream reaches designated as critical habitat in the Snake River basin are on the CWA 303(d) list for impaired water quality (IDEQ 2011). In addition to elevated temperatures, water quality in spawning and rearing areas in the Snake River has been impaired by high levels of sedimentation and by metal contamination potentially from mine waste (e.g., IDEQ 2001, IDEQ and EPA 2003, IDEQ 2011).

Migration habitat quality for Snake River sockeye salmon has also been severely degraded, primarily by the development and operation of dams and reservoirs on the mainstem Columbia and Snake Rivers (NMFS 2008b). Hydroelectric development has modified natural flow regimes in the migration corridor, causing higher water temperatures and changes in fish community structure that have led to increased rates of piscivorous and avian predation on juvenile salmon, and delayed migration for both adult and juveniles. Physical features of dams such as turbines also kill migrating fish.

3.2.4.2 Lake Ozette Sockeye Salmon

The Lake Ozette sockeye salmon ESU was federally listed as threatened in 1999 (64 FR 14528), and this listing was reaffirmed in 2005 (70 FR 37160).

The NMFS adopted the recovery plan for Lake Ozette sockeye salmon on May 29, 2009 (74 FR 25706). The recovery plan describes the ESU's population structure, identifies spawning aggregations essential to recovery of the ESU, establishes recovery goals for the population, and recommends habitat, hatchery, and harvest actions designed to contribute to the recovery of the ESU (NMFS 2009b).

Lake Ozette sockeye are distinguished from other Washington sockeye ESUs based on unique genetic characteristics, early river entry, the relatively large adult body size, and large average smolt size relative to other coastal Washington sockeye populations (Gustafson et al. 1997).

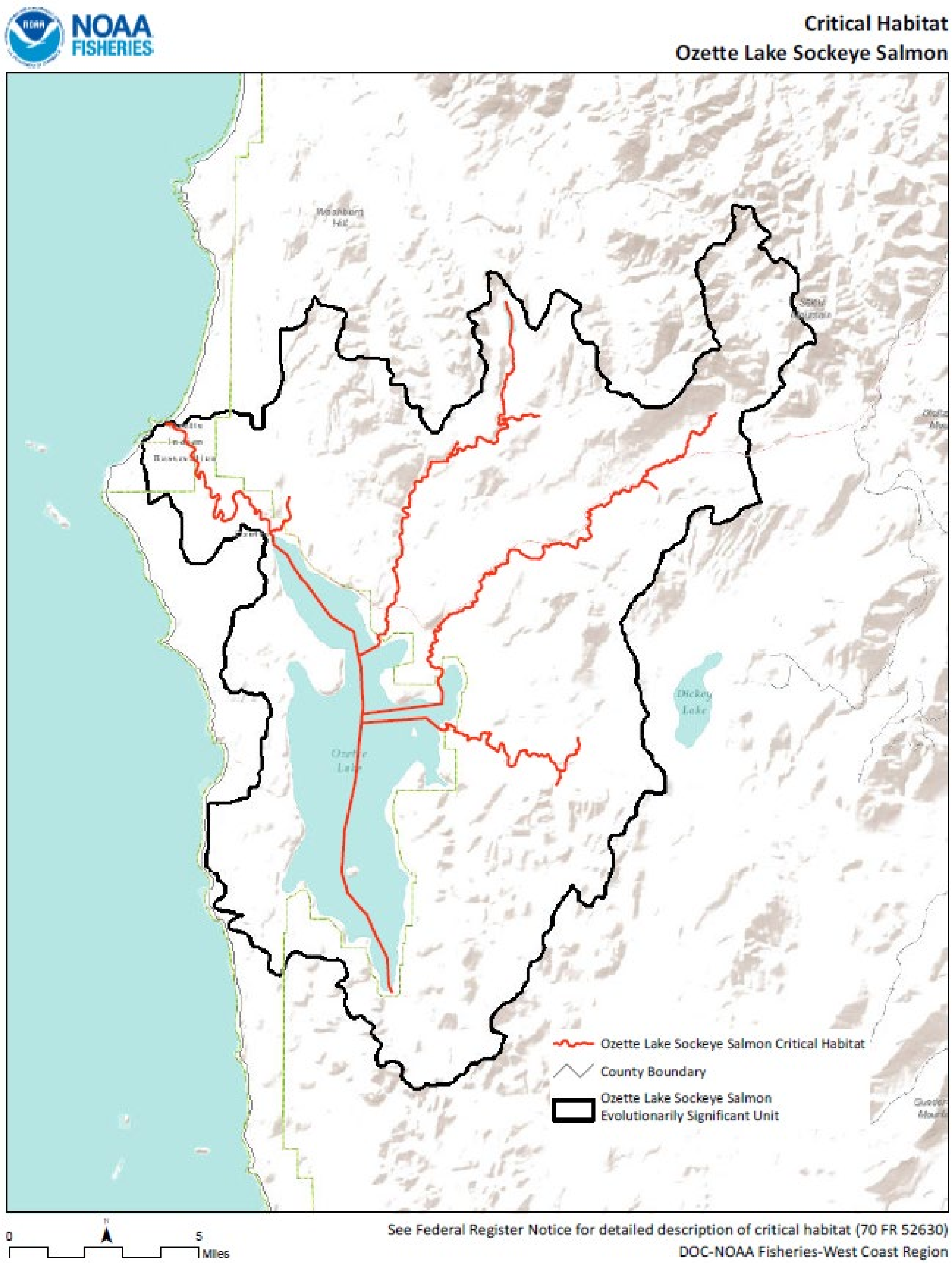
3.2.4.2.1 Distribution

The freshwater habitat for the Lake Ozette sockeye ESU is contained within a single watershed, which includes the Ozette River, Lake Ozette, and associated tributaries.

3.2.4.2.2 Critical Habitat

Critical habitat for Lake Ozette sockeye salmon was designated for Washington in 2005 and includes areas shown in Figure 3-11 (70 FR 52630). There are approximately 66 km (41 miles) of stream habitats and 19 square kilometers (sq km) (12 square miles) of lake habitats designated as critical habitat for Lake Ozette sockeye salmon. Critical habitat is defined as the stream channels within the designated stream reaches and extends laterally to the ordinary high-water line. In areas where ordinary high-water line has not been defined, the lateral extent is defined by the bankfull elevation. Critical habitat in lake areas is defined by the perimeter of the water body as displayed on standard 1:24,000 scale topographic maps or the elevation of ordinary high water, whichever is greater.

In the final critical habitat designation for Lake Ozette sockeye, NMFS excluded Native American tribal lands and other habitat areas where the benefits of exclusion outweighed the benefits of inclusion. NMFS excluded less than 1.6 km (1 mile) of stream because it overlaps with tribal lands. Approximately 3.2 km (2 miles) of stream were excluded because they are covered by a habitat conservation plan.



Source: (NOAA Fisheries 2016f)

Figure 3-11. Critical Habitat for Lake Ozette Sockeye Salmon.

PBFs for Lake Ozette sockeye include the following:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development;
- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams, and beaver dams;
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival;
- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh water and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation;
- Nearshore marine areas free of obstruction and excessive predation with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; also, natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and
- Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation

3.2.4.2.3 Life History

Adult sockeye return to the Ozette watershed from mid-April through mid-August, with peak entry from mid-May through June (Haggerty et al. 2015 as cited in, NMFS 2016b). Adult sockeye salmon hold for three to nine months (average of six months) in the lake prior to spawning (Haggerty et al. 2009). The current, known spawning distribution of Lake Ozette sockeye salmon is limited to Olsen's Beach, Allen's Beach, Umbrella Creek, and Big River.

Within the Ozette watershed beach-spawning sockeye salmon return, spawn, and die almost exclusively at age four, which limits potential genetic exchange between fish in the four different brood lines. Otolith data from spawners collected between 2000 and 2004 indicate that 96% and 97% of spawning adults were four years old at Olsen's and Allen's Beaches, respectively (Haggerty 2015). In creek-spawning sockeye, three and five year old sockeye make up a small proportion of non-hatchery runs but can make up a significant portion of the returning hatchery-raised fish. Umbrella Creek spawners of age three, four, and five during the 2000 to 2004 time period averaged 2%, 90%, and 8% of sampled fish, respectively. Otolith age data for hatchery sockeye returning to Umbrella Creek from 2000 to 2012 show that the proportion of four-year-old sockeye among spawners ranged from 16% to 100% with an average of 69%. The proportion of three year old hatchery-raised sockeye spawners returning to Umbrella Creek ranged from 0% to 81%, with an average of 22%. The proportion of age-five sockeye ranged from 0% to 64%, with an average of 9%. Over 99% of the juvenile sockeye emigrating from the lake to the ocean are one year or older, indicating that few juvenile sockeye rear in the lake for more than one summer ((Jacobs et al. 1996); MFM, unpublished otolith age data).

3.2.4.2.4 Current Stressors and Threats

The primary limiting factors for Lake Ozette sockeye salmon include the potential impacts of climate change, such as warming water temperatures and changes in precipitation that could alter the timing and magnitude of flows needed to transport sockeye fry into Lake Ozette. Also, increased frequency of rain-on-snow events could increase the frequency and intensity of floods in mainstem spawning areas, leading to scouring flows and impacted survival and productivity of non-hatchery sockeye salmon (Haggerty et al. 2009).

3.2.5 Steelhead (*Oncorhynchus mykiss*)

Steelhead trout is an anadromous salmonid fish that can live up to 11 years and grow up to 25 kg (55 pounds) and 120 cm (47 inches) long, though most fish tend to be much smaller than that (NMFS 2016g). They are distinguishable from other salmonids by their dark olive color, speckled body, and pinkish red stripe along their sides, though they tend to remain more silver while in the marine environment (than the non-migratory rainbow trout [*O. mykiss*]) (NMFS 2016g).

Steelhead in the NW mature in one of two distinct modes, either stream-maturing or ocean-maturing (NMFS 2016g). Stream-maturing individuals (also called summer-run steelhead) return to freshwater streams prior to becoming fully mature, typically between May and October; spawning occurs several months later. Ocean-maturing individuals (also called winter-run steelhead) mature while at sea and reenter freshwater streams during November and April. Coastal streams tend to be dominated by ocean-maturing groups, whereas inland streams tend to be dominated by stream-maturing groups (NMFS 2016g).

Spawning occurs over coarse substrates (gravel) in cold, fast-flowing streams with highly oxygenated waters, and spawning may occur more than once (NMFS 2016g). After hatching (three to four weeks after spawning), steelhead may reside in freshwater streams for up to seven years before migrating into estuaries to smolt, and they may reside in marine environments for three years (NMFS 2016g). A small number of steelhead actually return to freshwater after their first year only to migrate back out without spawning; this behavior is irregular among salmonid species.

Steelhead typically feed on zooplankton as juveniles and shift to larger insects, mollusks, crustaceans, and fish as adults (NMFS 2016g).

3.2.5.1 Snake River Basin Steelhead Trout

The Snake River Basin (SRB) steelhead trout was listed as a threatened ESU on August 18, 1997 (62 FR 43937), with a revised listing as a Distinct Population Segment (DPS) on January 5, 2006 (71 FR 834).

3.2.5.1.1 Distribution

The SRB steelhead DPS occupies the Snake River Basin, which drains portions of southeastern Washington, northeastern Oregon, and north/central Idaho. This species includes all naturally spawning steelhead populations below natural and manmade impassable barriers in streams in the SRB, as well as the progeny of six artificial propagation programs (71 FR 834). The SRB steelhead listing does not include resident *O. mykiss* (rainbow trout) that co-occur with (migratory) steelhead.

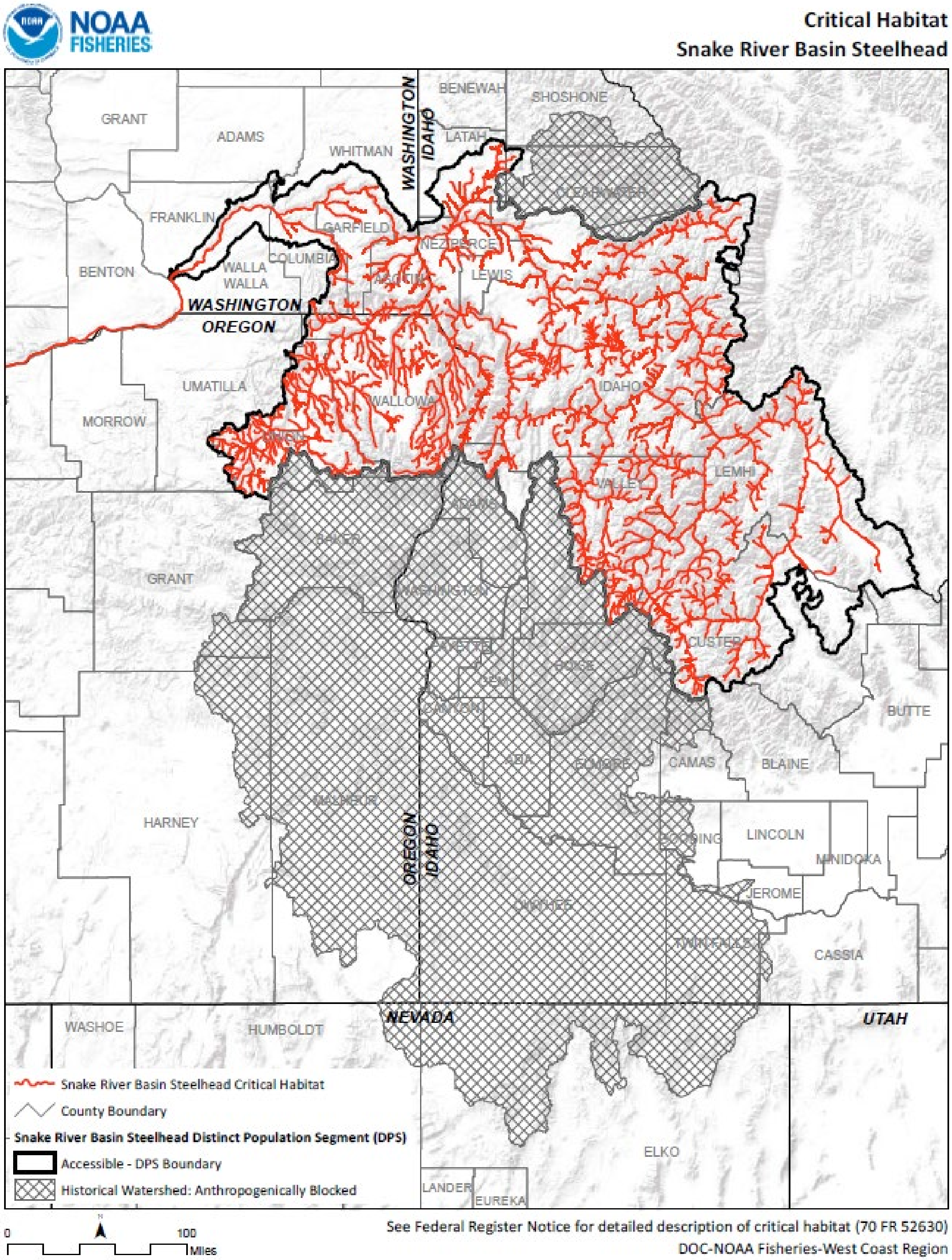
3.2.5.1.2 Critical Habitat

Critical habitat for the SRB steelhead trout DPS was designated for Idaho, Oregon, and Washington in 2005 and includes areas shown in Figure 3-12 (70 FR 52630). Specific stream reaches are designated within the Lower Snake, Salmon, and Clearwater River Basins. Habitat areas within the DPS's geographical range that are excluded from critical habitat designation are defined in 70 FR 52630. Table 3-3 describes the PBFs for steelhead critical habitat for multiple DPS/ESUs, including the SRB steelhead DPS.

Table 3-3. Physical and Biological Features of Designated Steelhead Critical Habitats

Critical Habitat Type[a]	Physical and Biological Feature(s)	Applicable Life Stage
Freshwater spawning	Water quality, water quantity, and substrate	Spawning, incubation, and larval development
Freshwater rearing	Water quantity and floodplain connectivity to form and maintain physical habitat conditions	Juvenile growth and mobility
	Water quality and forage[b]	Juvenile development
	Natural cover[b]	Juvenile mobility and survival
Freshwater migration	Free of artificial obstructions, water quality and quantity, and natural cover[c]	Juvenile and adult mobility and survival
Estuarine	Water quality, water quantity, and salinity	Juvenile and adult physiological transitions
	Natural cover and forage[a]	Juvenile growth and maturation and adult conservation
Nearshore marine	Water quality, water quantity, forage,[a] natural cover[b]	Juvenile growth and maturation
Offshore marine	Water quality and forage[a]	Juvenile growth and maturation

Notes:
[a] Habitat types are based on terminology used in the Federal Register designating critical habitat for steelhead
[b] Forage includes aquatic invertebrate and fish species that support growth and maturation.
[c] Natural cover includes shade, large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.



Source: (NOAA Fisheries 2016h)

Figure 3-12. Critical Habitat for Snake River Basin Steelhead Trout.

3.2.5.1.3 Lif e History

Adult SRB steelhead enter the Columbia River from late June to October to begin their migration inland. After holding over the winter in larger rivers in the SRB, steelhead disperse into smaller tributaries to spawn from March through May. Earlier dispersal occurs at lower elevations, and later dispersal occurs at higher elevations. Juveniles emerge from the gravels four to eight weeks after hatching, and move into shallow, low-velocity areas in side channels and along channel margins, where they are able to escape high velocities and predators (Everest and Chapman 1972). Juvenile steelhead then progressively move toward deeper water as they grow in size (Bjornn and Reiser 1991). Juveniles typically reside in freshwater for one to three years, although this species displays a wide diversity of life histories. Smolts migrate downstream during spring runoff, which occurs from March to mid-June depending on elevation, and typically spend one to two years in the ocean.

SRB steelhead exhibit a diversity of life-history strategies, including variations in freshwater and marine residence times. Traditionally, fisheries managers have classified SRB steelhead into two groups, A-run and B-run, based on age at return to freshwater, adult size at return, and migration timing. A-run steelhead tend to be smaller than B-run steelhead, and they predominantly spend one year in the ocean. Conversely, B-run steelhead are larger, and most individuals return after two years in the ocean. Most Snake River populations support a mixture of the two run types. The highest percentage of B-run fish are in the upper Clearwater River and the South Fork Salmon River; moderate percentages of B-run fish are in the Middle Fork Salmon River; and a very low percentages of B-run fish are in the Upper Salmon River, Grande Ronde River, and Lower Snake River (NWFSC 2015). A-run fish make up the remainder of those populations.

3.2.5.1.4 Current Stressors and Threats

Limiting factors for SRB steelhead trout include substantial modification of the seaward migration corridor by hydroelectric power development on the mainstem Snake and Columbia Rivers, widespread habitat degradation and reduced streamflows throughout the Snake River basin (Good et al. 2005), and reduced genetic integrity caused by a high proportion of hatchery fish (Good et al. 2005, Ford et al. 2011).

Spawning and rearing habitat quality in tributary streams in the Snake River varies from excellent in wilderness and roadless areas to poor in areas subject to intensive human land uses (NOAA Fisheries 2016p). Critical habitat throughout much of the Interior Columbia (which includes the Snake River and the MCR) has been degraded by intensive agriculture, alteration of stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer streamflows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in non-wilderness areas. Human land use practices throughout the basin have caused streams to become straighter, wider, and shallower, thereby reducing rearing habitat availability and impairing water temperature.

In many stream reaches designated as critical habitat in the SRB, streamflows are substantially reduced by water diversions (NOAA Fisheries 2016p). Withdrawal of water, particularly during low-flow periods that commonly overlap with agricultural withdrawals, often increases summer stream temperatures, blocks fish migration, strands fish, and alters sediment transport (Spence et al. 1996). Reduced tributary streamflow has been identified as a major limiting factor for SRB steelhead in particular (NOAA Fisheries 2016p).

Many stream reaches designated as critical habitat for these species are on the CWA 303(d) list for impaired water quality (e.g., due to elevated water temperature) (IDEQ 2011). Many areas (e.g., Upper Grande Ronde) that were historically suitable rearing and spawning habitat are now unsuitable due to high summer stream temperatures. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water for agricultural or municipal use all contribute to elevated stream temperatures. Water quality in spawning and rearing areas in the Snake River has also been impaired by high levels of sedimentation and by heavy metal contamination from mine waste (e.g., IDEQ 2001, IDEQ and EPA 2003, IDEQ 2011).

Migration habitat quality for SRB steelhead has also been severely degraded, primarily by the development and operation of dams and reservoirs on the mainstem Columbia and Snake Rivers (NMFS 2008b). Hydroelectric development has modified natural flow regimes in the migration corridor, causing higher water temperatures and changes in fish community structure. This has led to increased rates of piscivorous and avian predation on juvenile steelhead, and delayed migration for both adult and juveniles. Physical features of dams such as turbines also kill migrating fish.

3.2.5.2 Puget Sound Steelhead Trout

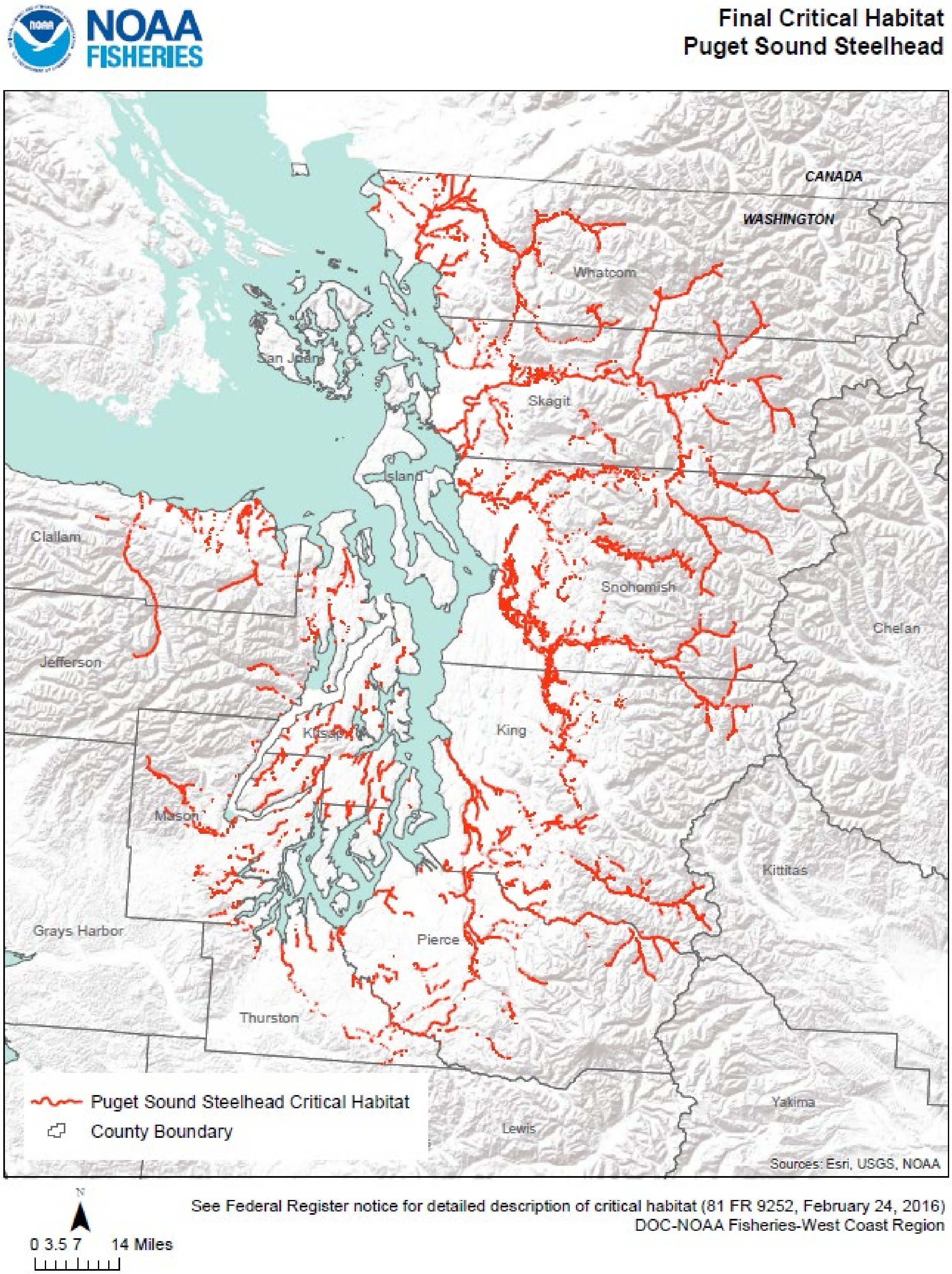
The Puget Sound steelhead DPS was federally listed as threatened in 2007 (72 FR 26722).

3.2.5.2.1 Distribution

The Puget Sound steelhead DPS includes all naturally spawned, anadromous steelhead populations in river basins draining to the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington. The Puget Sound steelhead DPS area is bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive). The Puget Sound steelhead DPS also includes six hatchery stocks that are considered relatively similar (genetically) to their associated non-hatchery counterparts (79 FR 20802). Non-anadromous "resident" *O. mykiss* occur within the range of Puget Sound steelhead DPS but are not part of the DPS due to marked differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007).

3.2.5.2.2 Critical Habitat

Critical habitat was designated for the Puget Sound steelhead DPS on February 24, 2016 (81 FR 9252). There are approximately 3,269 km (2,031 miles) of freshwater and estuarine habitat designated as critical habitat for Puget Sound steelhead (Figure 3-13). There are 18 sub-basins containing 66 watersheds within the range of the Puget Sound steelhead DPS. The PBFs for West Coast steelhead critical habitat are provided in Table 3-3.



Source: (NOAA Fisheries 2016l)

Figure 3-13. Critical Habitat for Puget Sound Steelhead Trout.

3.2.5.2.3 Life History

Puget Sound steelhead trout exhibit one of two distinct life history strategies based on whether individuals return in the summer or winter. Winter-run stealhead are the predominant group in the Puget Sound DPS, which means that most steelhead mature in the ocean and return to streams to spawn in winter or early spring (Myers et al. 2015). In lowland, rain-dominated streams, steelhead tend to return earlier than in higher elevation, snowmelt dominated streams.

3.2.5.2.4 Current Stressors and Threats

Limiting factors for Puget Sound steelhead trout include widespread declines in adult abundance (total run size) despite significant reductions in harvest, reduced diversity resulting from two hatchery steelhead stocks (i.e., Chambers Creek and Skamania), uncertain but weak status of summer-runs, and reduced spatial structure. Reduced habitat quality and quantity are also key limitations. The major categories of human activities with the potential to impact Puget Sound steelhead PBFs include forestry, grazing, agriculture, road building/maintenance, channel modifications/diking, urbanization, sand and gravel mining, mineral mining, dams, irrigation impoundments and withdrawals, vessel traffic, wetland loss/removal, beaver removal, and exotic/invasive species introductions. In addition to these, the harvest of salmonid prey (e.g., herring, anchovy, and sardines) adversely influences nearshore marine PBFs.

Dams have dramatically affected steelhead habitat use in a number of Puget Sound sub-basins. In addition to eliminating accessible habitat, dams affect habitat quality by changing river hydrology, temperature, downstream gravel recruitment, and large woody debris movement. Dams have impeded upstream access to historical steelhead habitat in the Middle Fork Nooksack, Baker, Cedar, Green, White, Nisqually, and North Fork Skokomish Rivers. "Trap-and-haul" programs (capture of live spawners and transport above impassible dams) have made passage of Puget Sound steelhead above the dams on the Baker and White Rivers possible. A smolt collection facility has similarly allowed downstream passage of juveniles possible on the Baker River. On the White River, downstream migrants can pass directly through the dams.

Urban development has dramatically altered many of the lower reaches of rivers and their tributaries in Puget Sound. Urbanization has destroyed historical land cover (e.g., forests) and exchanged it for large areas of imperious surfaces (e.g., roads). Wetland and riparian habitat loss has dramatically changed urban stream hydrology by increasing flood frequency and peak flows during storm events while decreasing groundwater-driven summer flows. Conversion to agricultural land has impacted river morphology, since much of this type of development occurs in river floodplains. Dike construction, bank hardening, and channelization have reduced river braiding and sinuosity. Constricting a river, especially during high flow events, increases the likelihood of gravel scour and dislocation of rearing juveniles.

Habitat blockage and/or degradation occur throughout the Puget Sound steelhead DPS range. In general, upper tributaries have been adversely affected by forest practices, whereas lower tributaries and mainstem rivers have been degraded by agriculture and/or urbanization. Diking for flood control, draining and filling freshwater and estuarine wetlands, and sedimentation from timber harvests and urban development are cited as problems throughout the Puget Sound steelhead DPS (Washington Department of Fisheries et al. 1993). Bishop and Morgan (1996) identified a variety of stream habitat limitations in the range of this species including flow regime changes, sedimentation, high temperatures (in the Dungeness, Elwha, Green/Duwamish, Skagit, Snohomish, and Stillaguamish Rivers), streambed instability, estuarine loss, large woody debris loss (in the Elwha, Snohomish, and White Rivers), pool habitat loss (in the Nooksack, Snohomish, and Stillaguamish Rivers), and blockage or passage problems associated with dams or other structures (in the Cedar, Green/Duwamish, Snohomish, and White Rivers).

3.2.5.3 Upper Columbia River Steelhead Trout

The UCR steelhead DPS was listed as endangered on August 18, 1997 (62 FR 43937), and its status was upgraded to threatened on January 5, 2006 (71 FR 834). The threatened status was affirmed on August 15, 2011, after the five-year status review (76 FR 50448).

3.2.5.3.1 Distribution

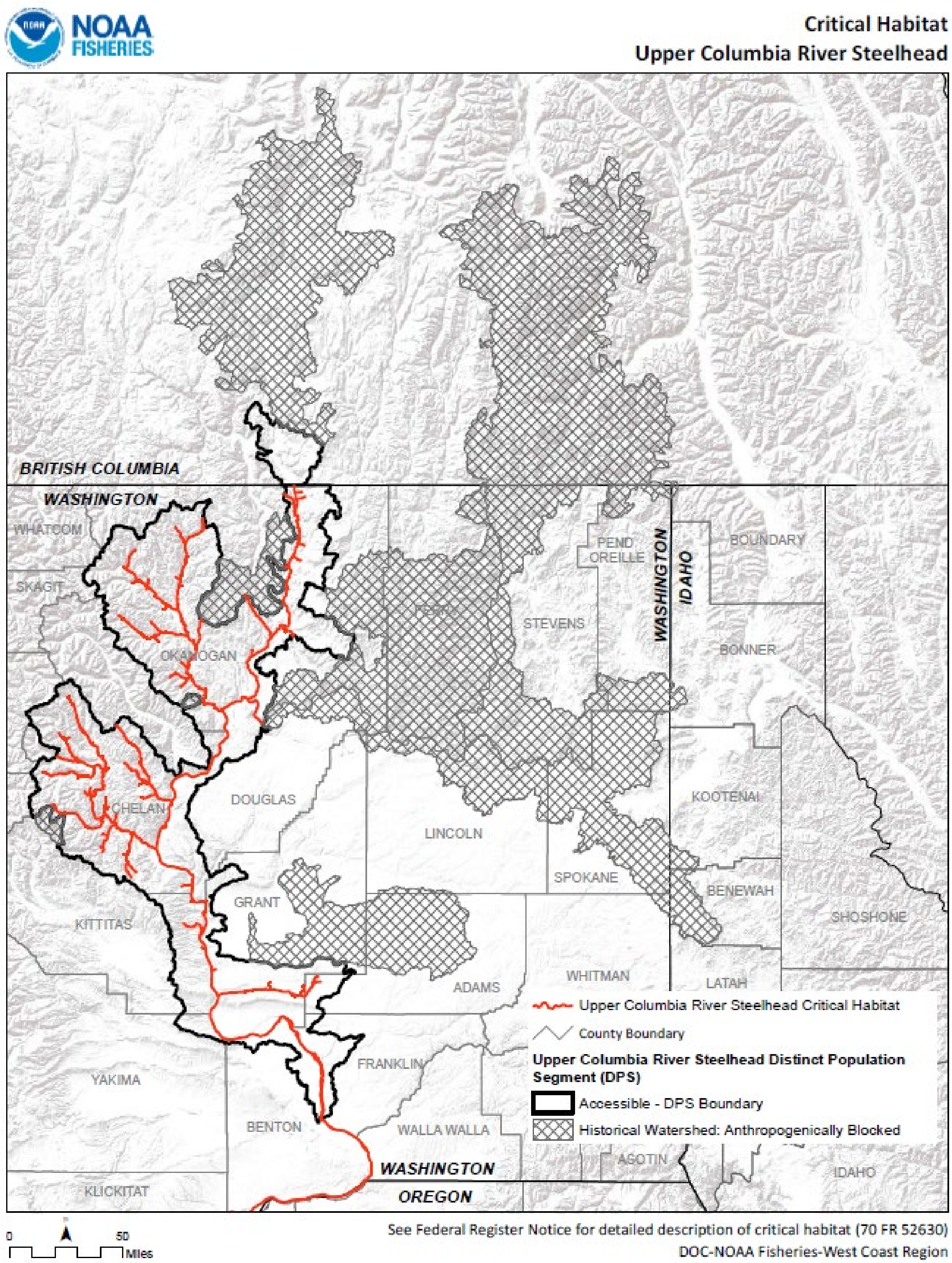
The UCR steelhead DPS includes all naturally spawned populations of steelhead in streams in the Columbia River Basin upstream from the Yakima River in Washington to the US-Canada border (62 FR 43937). There are four populations of UCR steelhead included in the UCR steelhead DPS: the Wenatchee, Entiat, Methow, and Okanogan populations. Six artificial propagation programs are also considered part of the DPS.

3.2.5.3.2 Critical Habitat

Critical habitat for UCR steelhead trout was designated for Oregon and Washington in 2005 and includes freshwater areas shown in Figure 3-14 (70 FR 52630). The PBFs of freshwater spawning sites include water flow, water quality, temperature conditions, and suitable substrate for spawning and incubation. These features are essential to conservation because without them the species cannot successfully spawn and produce offspring. However, there are only a few locations where spawning occurs in the Columbia River for UCR steelhead. The PBFs for West Coast steelhead critical habitat are provided in Table 3-3.

3.2.5.3.3 Life History

The life-history pattern of UCR steelhead is complex (Peven et al. 1994). Adults return to the Columbia River in the late summer and early fall. Unlike spring-run Chinook salmon, most steelhead do not move quickly up to spawning areas (i.e., tributaries). A portion of the returning run overwinters in mainstem reservoirs, passing over the UCR dams (up to Chief Joseph Dam, which is impassible) in April and May of the following year. Spawning occurs in the late spring. Juvenile steelhead generally spend one to three years (up to seven years) rearing in freshwater before migrating to the ocean. Most adult steelhead return to the UCR after one or two years at sea.



Source: (NOAA Fisheries 2016j)

Figure 3-14. Critical Habitat for Upper Columbia River Steelhead Trout.

3.2.5.3.4 Current Stressors and Threats

Limiting factors for UCR steelhead trout include adverse impacts from hydropower operations (i.e., modified hydrograph, increase in lentic conditions/ decrease in riverine conditions, passage barriers, altered temperatures and dissolved oxygen, and invasive species), riparian habitat degradation, decreased large wood recruitment, altered floodplain connectivity and function, altered channel structure and complexity, reduced streamflows, and hatchery-related impacts (i.e., reduced genetic diversity) (NMFS 2011b).

Habitat quality in tributary streams in the UCR range from excellent in wilderness and roadless areas to poor in areas subject to relatively heavy agricultural and urban development (Wissmar et al. 1994, NMFS 2009a). Critical habitat throughout much of the UCR has been degraded by intense agriculture, alteration of stream morphology (i.e., channel modifications and diking), riparian vegetation removal, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer stream flows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in developed areas.

Many stream reaches designated as critical habitat in the UCR are over-allocated under state water law, resulting in greater extraction of water than existing streamflow conditions can support. Withdrawal of water, particularly during low-flow periods that commonly overlap with agricultural withdrawals, often results in increased summer stream temperatures. Withdrawal can also block fish migration, strand fish, and alter sediment transport (Spence et al. 1996). Reduced tributary stream flow has been identified as a major limiting factor for all listed salmon and steelhead species in this area (UCSRB 2007, NMFS 2016c).

3.2.5.4 Middle Columbia River Steelhead Trout

The MCR steelhead DPS was listed as threatened on March 25, 1999 (64 FR 14517). The threatened status was reaffirmed on June 28, 2005 (70 FR 37160) and updated on April 14, 2014 (FR 79 20802).

3.2.5.4.1 Distribution

The MCR steelhead DPS includes all naturally spawned anadromous *O. mykiss* populations below impassable barriers in streams from above the Wind River in Washington and the Hood River in Oregon, upstream to, and including, the Yakima River in Washington but excluding *O. mykiss* from the Snake River Basin. Seven artificial propagation programs are also included in the DPS.

There are 17 extant populations (and three historically extirpated populations) in the MCR steelhead DPS (ICTRT 2003, 2005). The populations are further classified into four major population groups: John Day River (five extant populations), Umatilla/Walla Walla Rivers (three extant and one extirpated populations), Yakima River (four extant populations), and the Eastern Cascades group (five extant and two extirpated populations).

3.2.5.4.2 Critical Habitat

Critical habitat for the MCR steelhead DPS was designated for Oregon and Washington in 2005 and includes freshwater areas shown in Figure 3-15 (70 FR 52630). The PBFs for West Coast steelhead critical habitat are provided in Table 3-3.

3.2.5.4.3 Life History

MCR steelhead trout follow a summer-run pattern (consistent with other inland steelhead), and they mature in streams for up to one year before spawning (DOI 2011). Spawning migration starts in mid-May, and fish pass over Bonneville Dam in July and August (DOI 2011). Fry emerge from gravel between May and June, and juvenile MCR steelhead tend to smolt after two years in freshwater streams, after which they spend one to three years in the ocean before returning to freshwater (DOI 2011). MCR steelhead co-occur with non-anadromous rainbow trout, and they may not be reproductively isolated (Carmichael 2006).

3.2.5.4.4 Current Stressors and Threats

Stressors and threats to the MCR steelhead DPS and critical habitat are similar to those for the UCR steelhead DPS.

3.2.5.5 Lower Columbia River Steelhead Trout

LCR steelhead were federally listed as threatened in 2006 (71 FR 834).

3.2.5.5.1 Distribution

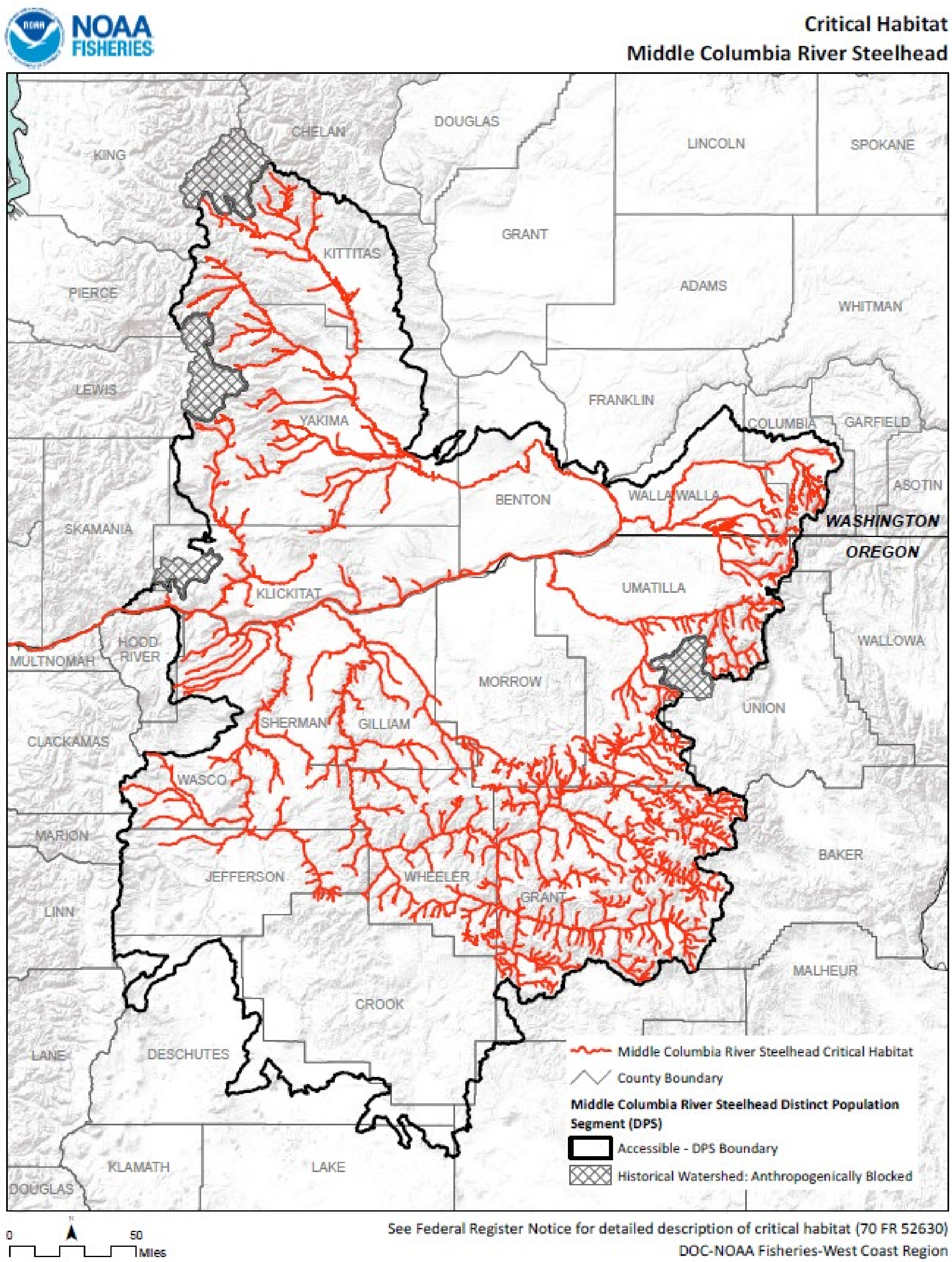
The LCR steelhead DPS includes all naturally spawned anadromous *O. mykiss* originating from below impassable barriers from rivers between the Cowlitz and Wind Rivers (inclusive) and the Willamette and Hood Rivers (inclusive). The DPS excludes fish originating from the UWR Basin above Willamette Falls. This DPS also includes steelhead from seven artificial propagation programs (79 FR 20802).

3.2.5.5.2 Critical Habitat

Critical habitat for LCR steelhead trout was designated for Oregon and Washington in 2005 and includes areas shown in Figure 3-16 (70 FR 52630). The PBFs for LCR steelhead critical habitat are described in Table 3-3.

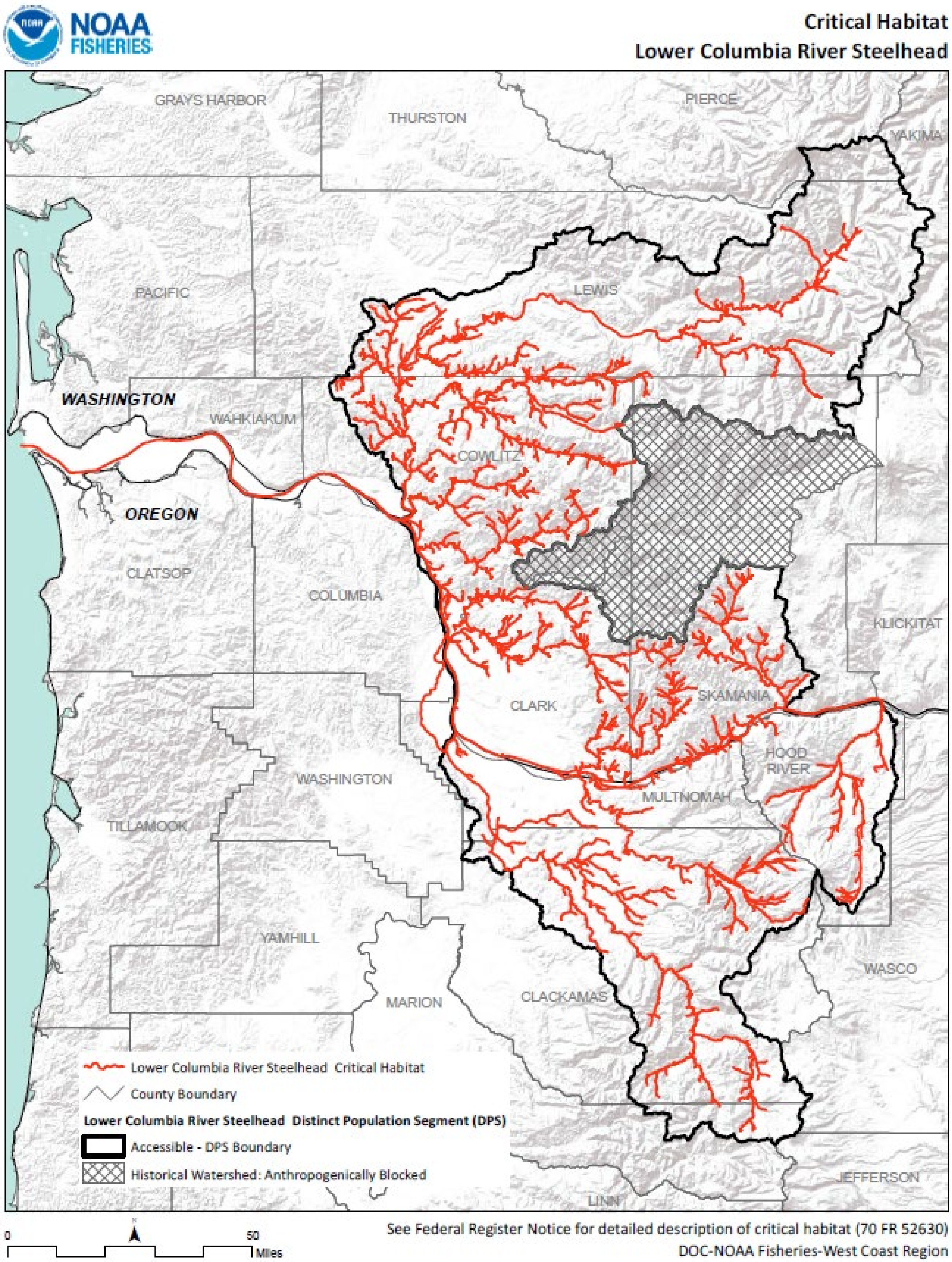
3.2.5.5.3 Life History

Steelhead in the LCR smolt after two years spent in freshwater, then spend an additional two years in marine waters before returning to freshwater to spawn (NOAA Fisheries 2015b). Steelhead may linger in freshwater streams for up to a year before spawning (NOAA Fisheries 2015b). Unlike other Pacific salmonids, steelhead are iteroparous (can spawn multiple times), though multiple spawning events are rare and mostly restricted to females (Nickelson et al. 1992).



Source: (NOAA Fisheries 2016e)

Figure 3-15. Critical Habitat for Middle Columbia River Steelhead Trout.



Source: (NOAA Fisheries 2016d)

Figure 3-16. Critical Habitat for Lower Columbia River Steelhead Trout.

3.2.5.5.4 Current Stressors and Threats

Limitations for the LCR steelhead DPS include interactions with hatchery fish (resulting in reduced genetic diversity), limited fish passage at dams, and habitat degradation. The conversion of floodplain habitat to agricultural or urbanized land uses has reduced steelhead habitat availability throughout the LCR region. Channelization and hydrological changes have reduced habitat complexity in the lower tributary/mainstem Columbia River interface, and the concomitant change in water temperatures is a likely stressor on the LCR steelhead DPS (NMFS 2013). Contamination is a growing concern for aquatic life and designated uses of the LCR (Counihan et al. 2013, Alvarez et al. 2014, Nilsen and Morace 2014, Nilsen et al. 2014), and Total Maximum Daily Loads are needed for many pollutants.

3.2.6 Pacific Eulachon (*Thaleichthys pacificus*) Southern DPS

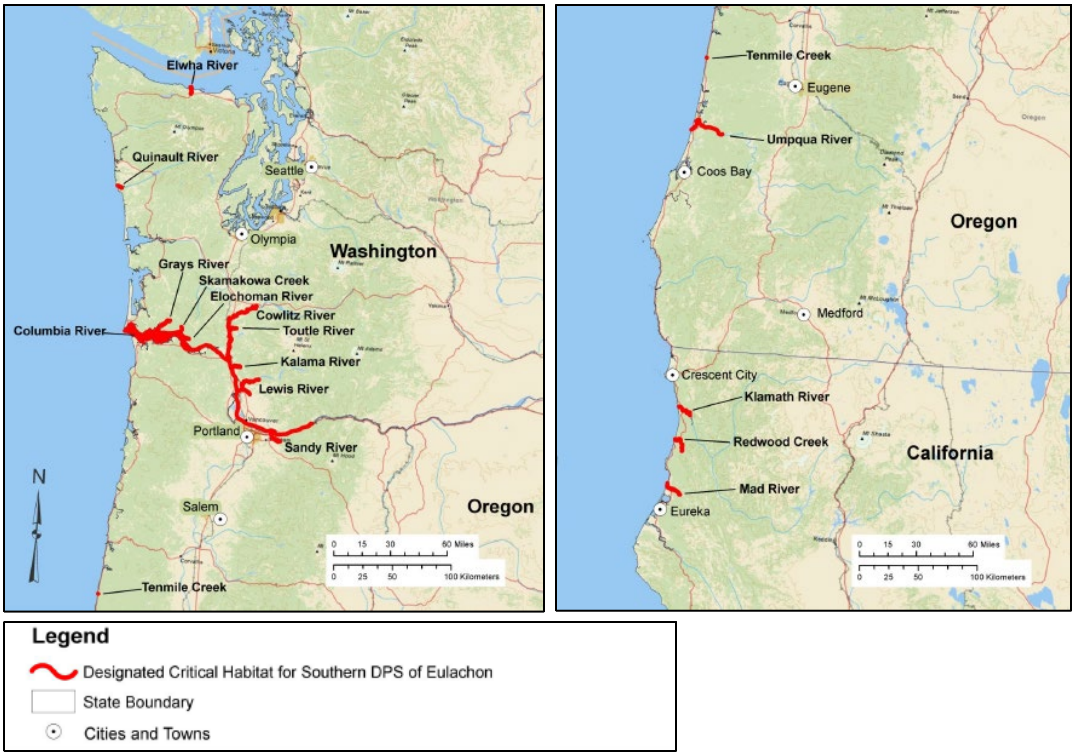
On March 16, 2010, the southern DPS of Pacific eulachon was listed as a threatened species (75 FR 13012).

3.2.6.1 Distribution

Pacific eulachon are endemic to the northeastern Pacific Ocean, ranging from northern California to southwest and south-central Alaska and into the southeastern Bering Sea. Puget Sound lies between two of the largest eulachon spawning rivers (the Columbia and Fraser Rivers) but lacks a regular eulachon run of its own (Gustafson et al. 2010). Within the NW, most eulachon production originates in the Columbia River Basin, and the largest and most consistent spawning runs return to the Columbia River mainstem and Cowlitz River. Adult eulachon have been found at several Washington and Oregon coastal locations, and they were previously common in Oregon's Umpqua River and the Klamath River in northern California. Runs occasionally occur in many other rivers and streams, though often erratically, appearing in some years but not others and only rarely in some river systems (Hay and McCarter 2000, Willson et al. 2006, Gustafson et al. 2010). Since 2005, eulachon in spawning condition have been observed nearly every year in the Elwha River by Lower Elwha Tribe fishery biologists. The Elwha is the only river within the US portion of Puget Sound and the Strait of Juan de Fuca that supports a consistent run of eulachon.

3.2.6.2 Critical Habitat

Critical habitat was designated for the southern DPS of eulachon on October 20, 2011 (76 FR 65324). Sixteen specific areas were designated as critical habitat within the states of California, Oregon, and Washington (Figure 3-17). The designated areas are a combination of freshwater creeks and rivers and their associated estuaries, comprising approximately 539 km (335 miles) of habitat. Areas designated for critical habitat in Washington include a large portion of the Columbia River (from the mouth to Bonneville Dam), the Grays, Elochoman, Cowlitz, Toutle, Kalama, Lewis, Quinault, and Elwha Rivers and Skamokawa Creek. No marine areas were designated as critical habitat. Lands of the Lower Elwha and Quinault Tribes are also excluded from critical habitat designation.



Source: 76 FR 65324

Figure 3-17. Critical Habitat for Southern DPS Pacific Eulachon in Washington and Oregon.

The PBFs essential to the conservation of the Pacific eulachon southern DPS were analyzed as three major categories reflecting key life history phases of eulachon. PBFs for freshwater spawning and incubation sites include water flow, quality, and temperature conditions; spawning and incubation substrates; and migratory access. PBFs for freshwater and estuarine migration corridors include waters free of obstruction; specific water flow, quality, and temperature conditions (for supporting larval and adult mobility); and abundant prey items (for supporting larval feeding after the yolk sac is depleted). The PBFs for marine nearshore and open water foraging habitat include suitable water quality and availability of prey.

3.2.6.3 Life History

Eulachon generally spawn in rivers fed by glaciers or snowpack that experience spring freshets. Since these freshets rapidly move eulachon eggs and larvae to estuaries, it is believed that eulachon imprint and home to an estuary into which several rivers drain rather than individual spawning rivers (Hay and McCarter 2000). Eulachon typically enter the Columbia River system from December to May, with peak entry and spawning during February and March (Gustafson et al. 2010). They spawn in the LCR mainstem and multiple tributaries of the LCR.

Eulachon eggs are commonly found attached to sand or pea-sized gravel, though eggs have been found on a variety of substrates, including silt, gravel-to-cobble sized rock, and organic detritus (Smith and Saalfeld 1955, Langer et al. 1977, Lewis et al. 2002). Upon hatching, stream currents rapidly carry newly hatched larvae to the sea. Eulachon return to spawning rivers at ages ranging from two to five years as a single age class. Prior to entering their spawning rivers, eulachon hold in brackish waters while their bodies undergo physiological changes in preparation for freshwater and to synchronize their runs. Eulachon then enter rivers, move upstream, spawn, and die to complete their semelparous life cycle (COSEWIC 2011a).

Eulachon are a short-lived, high-fecundity, high-mortality forage fish, and such species typically have extremely large population sizes. Fecundity estimates range from 7,000 to 60,000 eggs per female with egg-to-larva survival likely less than 1% (Gustafson et al. 2010). This may lead to recruitment events where only a small minority of spawning individuals contribute to subsequent generations (Hedgecock 1994). Unlike other important forage fish species (e.g., Pacific herring), Columbia and Fraser River spawning stocks of Pacific eulachon appear to be limited to a single age class, which makes them vulnerable to environmental perturbations and catastrophic events (Gustafson et al. 2010).

Eulachon are an important link in the food chain between zooplankton and larger organisms. Small salmon, lingcod (*Ophiodon elongates*), white sturgeon (*Acipenser transmontanus*), and other fish feed on small larvae near river mouths. As eulachon mature, they are consumed by a wide variety of predators (Gustafson et al. 2010) (e.g., humpback whale; *Megaptera novaeangliae*).

3.2.6.4 Current Stressors and Threats

Climate change impacts on ocean habitat are the most serious threat to persistence of the southern DPS of Pacific eulachon (Gustafson et al. 2010). Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary productivity and the structure of marine communities (ISAB 2007). In the marine environment, eulachon rely on cool ocean regions and the pelagic invertebrate communities therein (Willson et al. 2006). Warming ocean temperatures will likely alter these communities, making it more difficult for eulachon and their larvae to locate or capture prey (Roemmich and McGowan 1995, Zamon and Welch 2005). Warmer waters could also allow for the northward expansion of eulachon predator and competitor ranges, increasing the already high predation pressure on the species (Rexstad and Pikitch 1986, McFarlane et al. 2000, Phillips et al. 2007). Decreased snowpack, increased peak flows, decreased base flow, changes in the timing and intensity of stream flows, and increased water temperatures may impact freshwater eulachon habitat (Morrison et al. 2002). In most rivers, eulachon typically spawn well before the spring freshet, near the seasonal flow minimum. Alterations to stream flow timing may cause eulachon to spawn earlier or be flushed out of spawning rivers at an earlier date. Early emigration may result in asynchrony between eulachon entering the marine environment and seasonal upwelling (Gustafson et al. 2010).

Historically, bycatch of eulachon in the pink shrimp fishery along the US and Canadian coasts has been very high (composing up to 28% of the total catch by weight (Hay and McCarter 2000) (Olsen et al. 2000)). Prior to the mandated use of bycatch-reduction devices in the pink shrimp fishery, 32% to 61% of the total catch in the pink shrimp fishery consisted of non-shrimp biomass, made up mostly of Pacific hake (*Merluccius productus*), various species of smelt, including Pacific eulachon, yellowtail rockfish (*Sebastes flavidus*), sablefish (*Anoplopoma fimbria*), and lingcod (Hannah and Jones 2007). Bycatch of eulachon in these fisheries is still significant. The total estimated bycatch of eulachon in the Oregon and California pink shrimp fisheries ranged from 217,841 fish in 2004 to 1,008,260 fish in 2010 (Al-Humaidhi et al. 2012).

Hydroelectric dams block access to historical eulachon spawning grounds and affect the quality of spawning substrates through flow management, altered delivery of coarse sediments, and siltation. Dredging activities during the eulachon spawning run may entrain and kill adult and larval fish and eggs.

There are numerous activities that may affect the PBFs of Pacific eulachon critical habitat. Activities include dams and water diversions (e.g., Bonneville Dam); dredging and disposal of dredged material (e.g., on the Cowlitz and Columbia Rivers); in-water construction or alterations; contamination and runoff resulting in degraded habitat quality; port and shipping terminals; and salmon habitat restoration projects, which benefit salmon to the detriment of species like Pacific eulachon. The activities may impact PBFs by altering stream hydrology; water level, flow, temperature, and dissolved oxygen levels; erosion and sediment input/transport; physical habitat structure; vegetation; soils; nutrients and chemicals; fish passage; and estuarine/marine prey resources.

3.2.7 Green Sturgeon (*Acipenser medirostris*), Southern DPS

The southern DPS of green sturgeon was listed as threatened on April 6, 2005 (71 FR 17757) because the majority of spawning adults are concentrated in one spawning river (i.e., the Sacramento River) and at risk for extirpation due to catastrophic events. The ESA section 4(d) rule published by NMFS includes measures necessary to conserve the southern DPS of green sturgeon (75 FR 30714). The northern DPS of green sturgeon, which is not listed, spatially overlaps with the southern DPS, but is genetically distinct. Approximately 70% to 90% of the green sturgeon present in the Columbia River estuary and Willapa Bay are from the southern DPS, and 40% of green sturgeon in Grays Harbor are from the southern DPS (NMFS 2015d).

3.2.7.1 Distribution

Green sturgeon are distributed throughout the West Coast of North America (Colway and Stevenson 2007) (Rosales-Casian and Almeda-Jauregui 2009, NMFS 2015d), primarily north of Point Conception in California with seasonal (spring and winter) aggregation off Vancouver Island, British Columbia (NOAA Fisheries 2016m). The only known spawning river for the entire DPS occurs in the Sacramento River in California (Poytress et al. 2012), outside of the Action Area.

Major areas of non-spawning aggregations in the Action Area include Willapa Bay, Grays Harbor, and the Columbia River estuary (summer and fall), though these groups tend to be predominately composed of subadult sturgeon (WDFW and ODFW 2012, as cited in Moser and Lindley 2007, Lindley et al. 2008, Lindley et al. 2011, NMFS 2015d).

3.2.7.2 Critical Habitat

Critical habitat was designated for the southern DPS green sturgeon on October 9, 2009 (74 FR 52300). Freshwater habitat was designated in the mainstem of the Sacramento River downstream of the Keswick Dam, in the Feather River below Oroville Dam, in the Yuba River below

Dagueere Point Dam, and in the Sacramento-San Joaquin Delta. Marine critical habitat was designated in areas shallower than 110 m (361 ft) between Monterey Bay in California to the US-Canada Border in Washington, including the following bays and estuaries: San Francisco, Humboldt, Coos, Winchester, Yaquina, and Newhalem Bays; Willapa and Grays Harbors; and the Lower Columbia River Estuary (up to river km 74 [river mile; RM 46]). These critical habitat areas, where they overlap with the NW area, are shown in Figure 3-18.

The following PBFs were identified for freshwater and estuarine green sturgeon habitats:

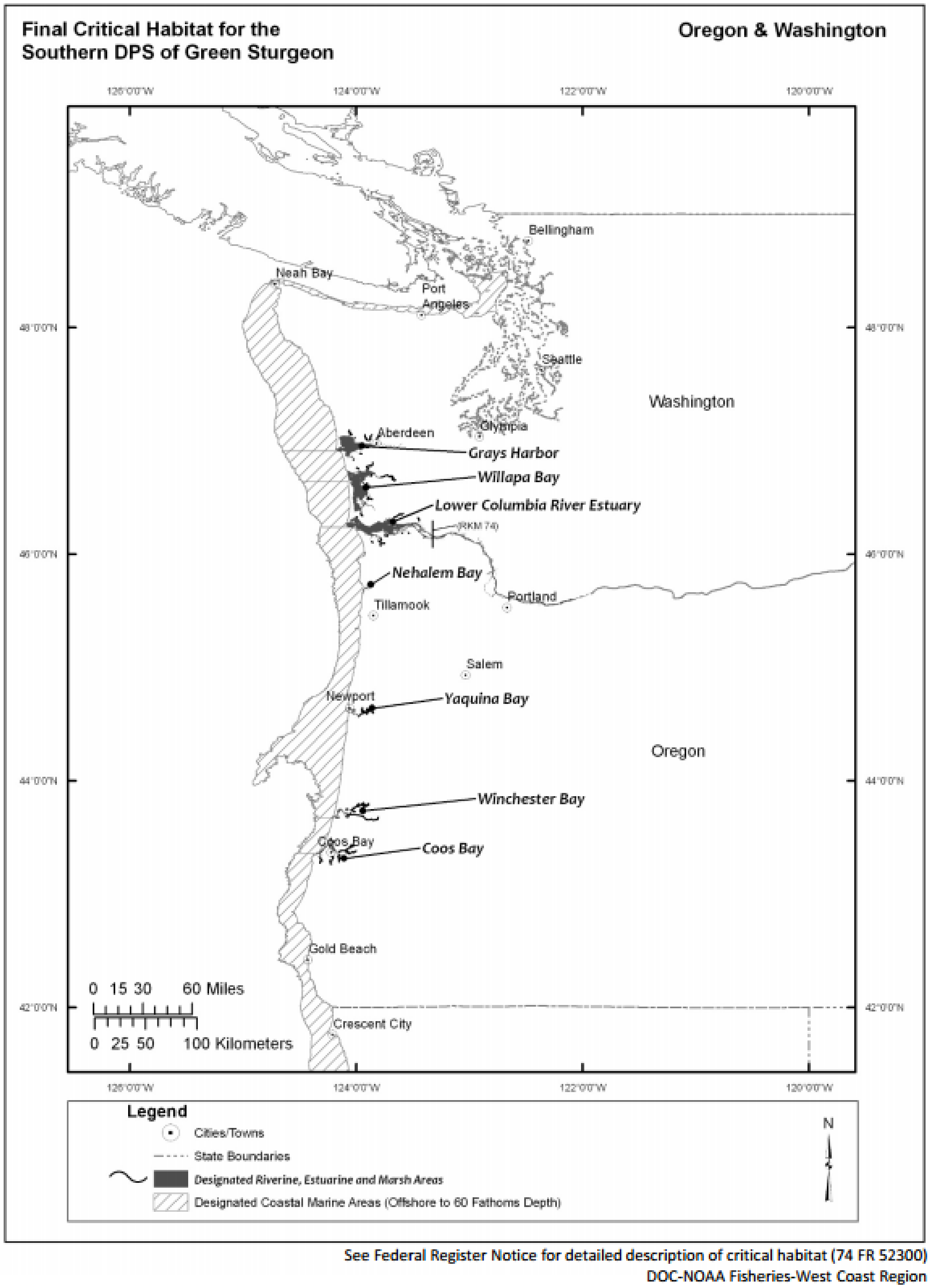
- Abundant prey for all life stages;
- Suitable substrates for egg deposition and development (e.g., bedrock sills, shelves, cobble or gravel, or hard clean sand); free of excessive siltation; availability of in-sediment voids for evading predators;
- Suitable flow regime to maintain normal behavior, growth, and survival of all life stages;
- Suitable water quality (i.e., temperature, salinity, dissolved oxygen, and “other chemical characteristics”) for normal behavior, growth, and viability of all life stages;
- Migratory corridors that allow for safe and timely passage;
- Adequately deep holding pools (≥5 m (16.4 ft); and
- Suitable sediment quality for normal behavior, growth, and viability of all life stages.

The following PBFs were identified for coastal nearshore marine habitats:

- Migratory corridors that allow for safe and timely passage;
- Suitable water quality; and
- Abundant prey items (e.g., benthic invertebrates and fishes).

3.2.7.3 Life History

Green sturgeon are one of two West Coast sturgeon species. They are distinguished from white sturgeon by their greenish color, sharper but fewer scutes, a relatively elongated head, and a conspicuous stripe of color down their ventral side. They have an iteroparous, anadromous life history, typically spawning every three to four years in deep freshwater pools with coarse substrates (NMFS 2015d). Sturgeon reach sexual maturity at approximately 15 years, and they can live for up to 70 years. Upon hatching, larval green sturgeon live on the bottom of rivers in coarse substrate, where they can avoid predators, absorb nutrients from their yolk sac, and grow into juveniles (NOAA Fisheries 2016n). Larvae then disperse downstream, spending one to four years in their natal stream before migrating into estuaries and marine waters. Green sturgeon spend the majority of their lives in the ocean, migrating long distances (NOAA Fisheries 2016n). They tend to reside at depths between 20 and 60 m (66 and 197 ft) (Huff et al. 2011). However, sturgeon show strong stream fidelity when selecting a spawning river. Adults return in large numbers to Washington and Oregon estuaries during the summer and fall, and spawning migrations typically occur between April and June (NOAA Fisheries 2016n). During the winter and spring, green sturgeon tend to migrate further north, where they form aggregations off Vancouver Island in British Columbia (NOAA Fisheries 2016n).



Source: Fisheries (2009)

Figure 3-18. Critical Habitat for Southern DPS Green Sturgeon in Oregon and Washington.

Green sturgeon feed using an elongated mouth appendage that sucks food and sediment from the sediment surface (NOAA Fisheries 2016m). Burrowing shrimp species (e.g., *Neotrypaea* spp.) are an important dietary component for subadult and adult green sturgeons, but they also eat fish (e.g., lingcod), crab (e.g., *Cancer* spp.), amphipods (e.g., *Anisogammarus* spp.), clams (e.g., *Cryptomya californica*), and polychaetes (Dumbauld et al. 2008). Predators of green sturgeon are not clear, but they may include pinnipeds (e.g., Steller sea lion [*Eumetopias jubatus*]), sharks (NMFS 2015d), and humans (through poaching or bycatch) (Israel and May 2007).

3.2.7.4 Current Threats

The significant decline in green sturgeon that has occurred in the last century is primarily due to harvest pressure and the destruction of spawning habitat or migration corridors (NOAA Fisheries 2016o). Since listing, the loss of freshwater habitat has remained a threat to the recovery of green sturgeon. Alterations to natural hydrology resulting from dams, channelization, sedimentation, and water withdrawal (for irrigation) are key culprits for degraded green sturgeon habitat (NOAA Fisheries 2016o). Flow is an important factor for green sturgeon larval survival and to cue adult spawning migrations (NMFS 2015d). Also, given the large number of spawning green sturgeon returning to the Sacramento River, genetic diversity may be relatively low. The impacts of invasive species, climate change, pesticide applications (i.e., carbaryl and imidacloprid), and future development are concerns (NMFS 2015d), but more data on their effects on green sturgeon are needed.

3.2.8 Southern Resident Killer Whale (*Orcinus orca*) DPS

Killer whales (often referred to as “orcas”) are the largest odontocete (toothed) dolphin species; adults tend to be 6.1 to 7.3 m (20 to 24 ft) in length, but killer whales may grow as large as 9.8 m (32 ft) (NOAA Fisheries 2017a). The DPS are social and are found in familial pods of 20 to 40 individuals led by a dominant matriarch (NOAA Fisheries 2017b, a). Stable social groups tend to include 2 to 15 individuals at a time, but large, temporary aggregations of the entire population occur, particularly in the summer (NOAA Fisheries 2017a). Aggregation and separation of groups tend to follow seasonal trends in prey availability and courtship and mating activities. Temporary associations of the pods, called “superpods,” of 50 or more individuals may form for a matter of days during late summer, consistent with when whales are mating (Barrett-Lennard and Heise 2007). Transient killer whales and offshore killer whales also occur in the area. It is nearly impossible to distinguish the three types of killer whales (i.e., resident, transient, and offshore killer whales) visually; however, their behaviors are substantially different. Transient killer whales generally travel in small groups and will hunt marine mammals. Offshore killer whales are uncommon, although groups of over 100 have been observed. Residents primarily consume salmonids. Killer whales use several types of calls, whistles, and clicks to communicate or to navigate and hunt (NOAA Fisheries 2017b).

Observations of Southern Resident Killer Whale (SRKW) behavior indicates that their active time is primarily budgeted to travel (70.4%), followed by foraging (21%), rest (6.8%), and socialization (1.8%) (Noren and Hauser 2016). Others have suggested that foraging accounts for a greater amount of activity, 40 to 67% (Ford 2006). Diving tends to be concentrated within the upper 30 m (98 ft) of the water column, with deeper dives of 100 to 200 m (328 to 656 ft) (or more) being occasional (Baird et al. 2005). Diving activity is greatest during the day, and dive depths and frequencies are greater for males than females (in adults) but are not greater for adults than juveniles (on average) (Baird et al. 2005). Killer whales are relatively recognizable due to their distinctive coloring and high level of surface activity (e.g., breaching and tail slapping), though SRKWs cannot easily be differentiated from transient individuals.

The historical abundance of SRKWs was between 140 and 400 whales (Olesiuk et al. 1990, Krahn et al. 2004). As of December 31, 2016, there were a total of 78 whales (CWR 2016). Of the three pods, the L pod is the largest at 35 members followed by J, which has 24 members, and then K, which only has 19 members (CWR 2016).

3.2.8.1 Distribution

SRKWs are present in the Salish Sea (Puget Sound, Strait of Juan de Fuca, and the Strait of Georgia) from spring to fall each year (NOAA Fisheries 2017a). In winter, some SRKWs remain in the Salish Sea, while others travel along the Washington, Oregon, and California coasts (as far south as central California) (NWFSC 2015). SRKWs may also travel north along the British Columbia border as far as the Queen Charlotte Islands and southeast Alaska. Between late spring and early autumn, SRKWs spend a significant portion of time in the Georgia Basin (Canada) and around the San Juan Islands of Washington following incoming salmon runs (NOAA Fisheries 2017a). Satellite tagged animals and tracking has identified an important winter through spring foraging area along the west coast of Washington down to the mouth of the Columbia River (Hanson et al. 2013). Although SRKWs can occur along the outer coast of Washington and Oregon at any time of the year, occurrence along the outer coast is more likely from late autumn to early spring.

SRKWs co-exist in areas with West Coast transient killer whales, but resident and transient groups generally do not have significant interactions (e.g., socializing or attacking one another) (Barrett-Lennard and Heise 2007).

3.2.8.2 Critical Habitat

Approximately 6,630 sq km (2,560 square miles) of critical habitat were designated for the SRKW at the end of 2006 (71 FR 69054) (Figure 3-19). Critical habitat includes all US waters within the Salish Sea, excluding 18 areas designated for military use (291 sq km; 112 square miles), any waters less than 6.1 m (20 ft) deep (at extreme high tide), and Hood Canal. Military installations were excluded from critical habitat as a matter of national security. The critical habitat was subdivided into three areas that provide necessary habitat elements: a core summer area (Haro Strait and San Juan Islands), Puget Sound, and the Strait of Juan de Fuca. These subareas correspond with seasonal prey (e.g., salmon) concentrations. The Strait of Juan de Fuca, Haro Strait (between San Juan Island and Vancouver Island), and Georgia Strait (in Canada) are narrow areas that concentrate salmon as they return to inland Washington and British Columbia, Canada waters from the Pacific Ocean.

PBFs for this critical habitat are stated in 71 FR 69054 as: water quality to support growth and development; prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth; and passage conditions to allow for migrating, resting, and foraging.

In 2014, a petition was submitted requesting revisions to SRKW critical habitat to include (in addition to those areas just noted) "Pacific Ocean marine waters along the West Coast of the US that constitute essential foraging and wintering areas…" (80 FR 9682). The petition also requests that the NMFS expand the PBFs for killer whales to include "protective in-water sound levels," which was initially considered as a PBF in 2006 but ultimately was not included (71 FR 69054). It is anticipated that the next steps related to the 2014 petition for critical habitat revision will be a proposed rule to revise critical habitat in 2017 (80 FR 9682).

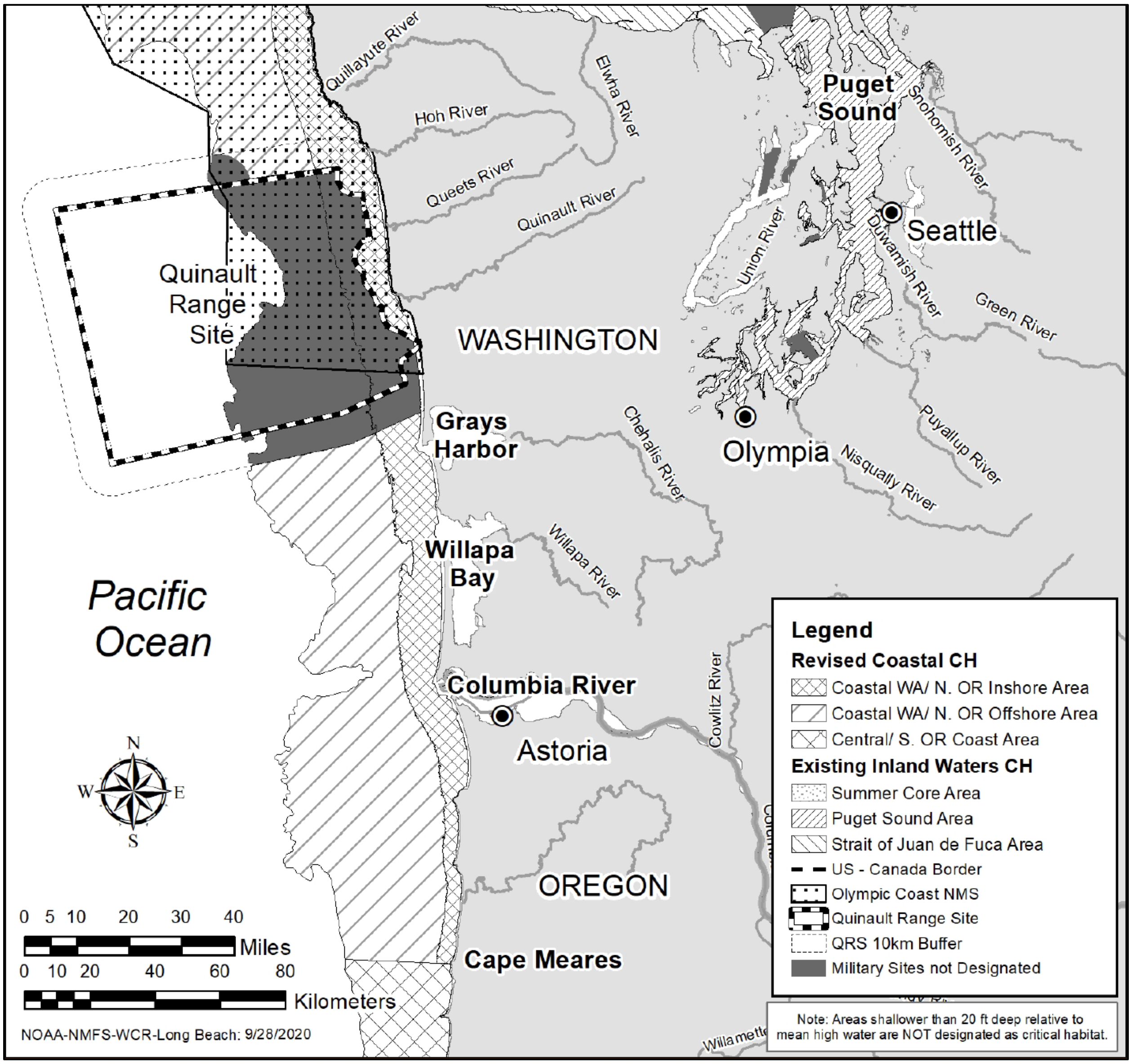


Figure 3-19. Map of southern resident killer whale critical habitat. Effective on Sep 1, 2021.

3.2.8.3 Life History

The SRKW is a long-lived species with a late onset of sexual maturity (NMFS 2008a). Mothers and offspring maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the SRKW population.

SRKWs live in inland and coastal marine waters, generally 49 to 55 m (160 to 180 ft) deep (Noren and Hauser 2016). Based on acoustic activity of whales, it is inferred that whale movements and presence are driven by local availability and abundance of salmon (Hanson et al. 2013), suggesting that prey are the most important habitat element for SRKWs. SRKWs preferentially consume Chinook salmon, but their diets also include squid and several other fish species (i.e., other salmonids and bottomfish) (Ford et al. 1998). Chinook salmon are the preferred salmonid prey item (Ford et al. 1998).

3.2.8.4 Current Stressors and Threats

Key stressors and threats to the SRKW population include human factors such as fishing, boating, water (and prey) quality, and noise pollution (e.g., caused by military activities) (NMFS 2015c). Water quality in Puget Sound is degraded (Johnson et al. 2010). For example, elevated concentrations of pollutants in the Salish Sea and elsewhere have been linked to elevated concentrations in salmon and in killer whales (Hickie et al. 2007, Krahn et al. 2007, Krahn et al. 2009, Lachmuth et al. 2010). Once in the environment, many contaminants accumulate in biological tissues, and some biomagnify up the food chain, reaching high levels in long-lived apex predators like SRKWs. Maternal transfer of persistent and bioaccumulative contaminants from mother to offspring increases killer whale body burdens in subsequent generations (by increasing the baseline burden at birth) (Krahn et al. 2009). Elevated concentrations of pollutants may result in reduced immune function and/or reproductive capability and mortality (Krahn et al. 2007, Krahn et al. 2009).

4. Environmental Baseline

The purpose of this section is to identify “the past and present effects of all Federal, State, or private activities in the action area, the anticipated effects of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the effect of State or private actions which are contemporaneous with the consultation in process” ("Endangered Species Act of 1973, As Amended,"), definition of “effects of the action.” These factors affect the species’ environment or critical habitat in the action area. The factors are described in relation to species’ biological requirements in the action area.

The action area is defined as all areas where all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action ("Endangered Species Act of 1973, As Amended,"). EPA’s action, i.e., the approval of Washington’s freshwater ammonia acute WQS, affects all freshwaters within the state boundaries that are used by ESA-listed species. Section 4 of this BE will therefore address the environmental baseline with respect to the species that may be affected by EPA’s action.

EPA evaluates the status of the environment by assessing the sources, occurrence, and concentrations of total ammonia nitrogen (TAN) in the action area. Sources include direct and indirect dischargers as well as land uses that influence the occurrence and concentration and thus potential exposure of ESA listed species to TAN. To understand the historic and current sensitivity of Washington fresh surface waters to TAN inputs, EPA also evaluated the variation of acute criteria concentrations using available pH and temperature data. These data were evaluated for spatial and temporal trends. Surface water chemistry data collected from 2000-2020 are included in the Environmental Baseline analysis, which was conducted to demonstrate that baseline conditions did not significantly change before or after EPA’s action in 2008. Refer to section 4.3.3 for details. Therefore, the environmental baseline is defined as all activities (defined above) that occurred before 2020.

4.1 Sources of Ammonia in Washington

Ammonia is a challenging pollutant to control given its ubiquitous presence in the environment – in the air, soil, water, plants as well as animals, its role in the complex nitrogen cycle, connections to both water and air quality and its critical role/use in supporting food production (crops and protein need nutrients like nitrogen) to meet population growth demands. Sources of ammonia include agricultural fertilizer applications (direct NH_3, and precursor nitrogen forms: ammonium nitrate, ammonium phosphate, urea and ammonium sulfate); industrial applications including metal finishing, production of pharmaceuticals and dyes, processing of crude oil, and extraction of metals; industrial cleaning agents, and decomposition of organic matter, fixation of atmospheric N_2 during biological processes, atmospheric gaseous exchange, wildfires and biota waste/discharge (USEPA 2013). More recently, the transportation sector has been identified as an important source as well in urbanized areas (Sun et al. 2017, Fenn et al. 2018).

It is also a challenging pollutant to measure and monitor due to the controls of pH and temperature, its “stickiness” to surfaces, ability to volatilize and its reactivity/ability to readily transform/be utilized by biological organisms and microbes (e.g., nitrification). As a result, quantitative refinements are still needed to constrain the entire ammonia budget, especially at more localized scales for less prominent sources. Ammonia is easily transformed into other species or forms of nitrogen in the environment, and, non-toxic forms are readily used in biological processes. Therefore, it is challenging to track within the environment which contributes to problems related to excess nutrient inputs (i.e., nitrogen) that can cause eutrophication and diminished water quality in aquatic ecosystems. Additionally, ammonia poses human health risks as a precursor to secondary fine particulate formation degrading air quality (Domingo et al. 2021).

Under the CWA, ammonia is regulated from point source dischargers. In these situations, “ammonia” refers to both unionized and ionized forms of reduced nitrogen as ammonia (NH_3) and ammonium (NH_4^+), that are collectively referred to as TAN (USEPA 2013). However, it is important to note that there are also indirect or nonpoint source inputs of ammonia into water and these sources are prominent components of the aquatic ammonia budget. Indirect or non-point source inputs of ammonia can come in the form of atmospheric deposition (as NH_3 gas and aerosol/particulate NH_4^+) and/or overland runoff caused by precipitation. NH_3 air emissions from stationary and mobile point sources, that contribute to downstream water quality are not regulated under the Clean Air Act (CAA). The only exception is that there are reporting requirements under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Emergency Planning and Right to Know Act (EPCRA) statutes for ammonia refrigeration facilities under section 112(r) to be in compliance with accidental release of hazardous chemicals under the Risk Management Program (40 CFR 68.130;[3] (USDA 2014)). Below, sources of ammonia are described within the context of the regulatory framework currently in place federally and specific to Washington State for direct (point) and indirect (non-point) dischargers.

4.1.1 Direct Dischargers

Direct dischargers of ammonia within Washington State primarily correspond to municipal and industrial dischargers and stormwater dischargers encompassing pollutant runoff from industrial facilities. As of February 10, 2021, Ecology has issued 90 National Pollutant Discharge Elimination Systems (NPDES) permits for facilities discharging to freshwater which include an ammonia limit and/or monitoring. Of these 90 permits there are 73 domestic wastewater permits, 6 reclaimed water permits, 9 industrial wastewater permits, and 2 industrial stormwater permits. From those 90 facilities with permit limits and/or ammonia monitoring requirements there are 35 facilities that have had one or more permit violations for ammonia between the period of January 1, 2016 to February 10, 2021. By discharge type, they include 27 domestic wastewater facilities, 2 reclaimed water facilities, 5 industrial wastewater facilities, and 1 industrial stormwater facility. In many instances, Washington’s existing chronic criteria for ammonia,

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[3] 40 CFR 68.130 can be found here:
https://www.ecfr.gov/cgi-bin/text-idx?SID=71aa3a66a25628df4e7074204c634042&mc=true&node=se40.17.68_1130&rgn=div8

rather than the acute criteria subject to this consultation, are used to establish NPDES permit limits.

Figure 4-1 depicts where the freshwater NPDES dischargers with ammonia limits and/or monitoring requirements are located throughout the state. The table in Appendix A includes a list of these permittees and their permit numbers.

4.1.1.1 Municipal and Industrial Dischargers

Municipal and industrial wastewater facilities are the primary dischargers with established ammonia limits under the NPDES program. Federal and state regulations require that NPDES permit limits be based on technology or water quality. Technology-based effluent limits are based on a minimum level of treatment for specific pollutants based on available treatment technologies as set by EPA regulation (40 CFR 125.3).[4] Alternatively, water quality-based effluent limits are calculated to ensure compliance with water quality standards of the receiving water (Chapter 173-201A WAC).[5]

Under the CWA, criteria are applicable to surface water conditions, therefore any regulated dischargers concerned with meeting water quality standards for ammonia should also actively monitor/control for pH and temperature in waste discharge to help regulate potential ammonia toxicity. Permits require dischargers to control temperature and pH prior to discharging to surface water and to conduct effluent monitoring to ensure compliance with ammonia criteria. Within the state of Washington, sewage treatment plants are the predominate type of facilities with permits containing ammonia limits. Some of the industrial discharger categories which have monitoring and/or ammonia limits include mining, dairies, and landfills.

[4] 40 CFR 125.3 can be found here:
https://www.ecfr.gov/cgi-bin/text-idx?SID=304c85a1fcbb6dbecf50a6e28664b131&mc=true&node=pt40.24.125&rgn= div5#se40.24.125_13

[5] Chapter 173-201A WAC can be found here: https://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A

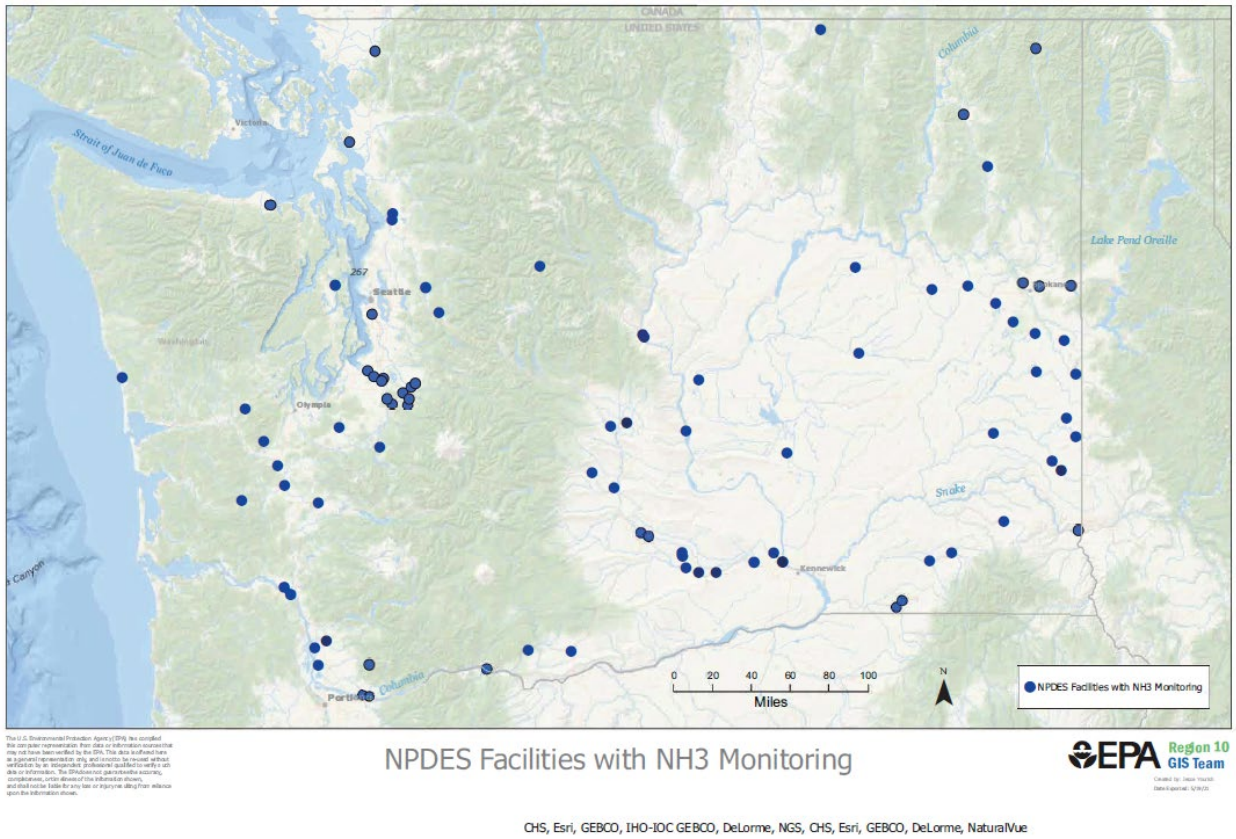

Figure 4-1. Facilities with National Pollutant Discharge Elimination Systems (NPDES) permits containing ammonia limits and/or monitoring across Washington.

4.1.1.2 Municipal and Industrial Stormwater

Ecology issues municipal stormwater general permits via the Municipal Separate Storm Sewer System (MS4) Program, which address stormwater runoff from municipal (phase I and II) facilities. Ecology also issues a statewide *Industrial Stormwater General Permit*,[6] for industrial facilities that conduct activities associated with any North American Industry Classification System groups. The Industrial Stormwater General Permit covers facilities that discharge stormwater into surface waters directly or via storm sewer systems if they have exposure potential, and are not covered by an NPDES permit that already addresses stormwater discharges. Ecology issues three additional industry specific stormwater general permits, which regulate the stormwater runoff from construction, sand and gravel, and boatyard operations. Facilities who are not covered by any of the general permits above, but are deemed as significant sources or that have a potential to violate state water quality standards may be required by the state to obtain individual permit coverage.

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[6] Washington's Industrial Stormwater General Permit can be found here: https://fortress.wa.gov/ecy/ezshare/wq/permits/ISGP_PermitFINAL.pdf

All stormwater permittees must implement a Stormwater Pollution Prevention Plan, which includes best management practices (BMPs) and discharge monitoring programs compliant with their general permit. Facilities with stormwater discharge subject to stormwater effluent limitations guidelines, New Source Performance Standards (40 CFR Subchapter N)[7] or Toxic Pollutant Effluent Standards (40 CFR subchapter D §129)[8] are not subject to coverage under this general permit and instead should seek individual permits or an industry-specific general permit. Of these stormwater general permits in Washington, only two facilities have general permit coverage pertinent to ammonia discharges.

4.1.2 Indirect Dischargers

Significant ammonia sources originate from agricultural and forestry activities, as well as atmospheric deposition. These sources are not easily regulated because the discharges are typically considered nonpoint source pollution, which is not regulated by the CWA nor EPA.

4.1.2.1 Agriculture and Forestry

Nitrogen is a critical nutrient for food production and population growth, but excessive amounts can have deleterious impacts in aquatic environments. Agricultural operations (Concentrated Animal Feeding Operations (CAFOs)[9] and fertilizer use for crop cultivation – both manure/sewage and chemical fertilizers) are a dominant source of nitrogen (including ammonia as direct gaseous emissions from fertilizer applications and animal waste), as well as, nutrient leaching or agricultural runoff into waterways from manure, litter and wastewater. 60-85% of ammonia emissions are estimated to originate from agricultural sources in the United States (Reis et al. 2009, USDA 2014) and the amount of annual manure, litter and wastewater generated by livestock in Washington contains an estimated 98-250 million lbs/year of nitrogen (Agriculture 2009).

Under the CWA, agricultural operations and associated non-point discharge/runoff is not easily regulated using NPDES permits with established ammonia limits unless direct discharge into surface waters is taking place. Yet, agricultural runoff is acknowledged as a prominent source of waterbody pollution (Xia et al. 2020). However, facilities that fall under the federal definition of CAFOs[9] can be considered as point-source dischargers through the NPDES program (CWA section 502(14)) and therefore can be regulated for various pollutants if they discharge to waters of the US. In 2017, Washington state issued the combined *Concentrated Animal Feeding Operation NPDES and State Waste Discharge General Permit*,[10] which applies to CAFOs directly discharging to surface waters (excludes agricultural stormwater) and groundwaters in the state. Currently, no CAFOs are regulated for ammonia effluent limits in the state.

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[7] 40 CFR Subchapter N can be found here: https://ecfr.federalregister.gov/current/title-40/chapter-I/subchapter-N

[8] 40 CFR subchapter D §129 can be found here: https://www.ecfr.gov/cgi-bin/text-idx?node=pt40.24.129&rgn=div5

[9] EPA's definition of CAFOs can be found here: https://www.epa.gov/sites/production/files/2015-08/documents/sector_table.pdf

[10] Washington's CAFOS General Permit can be found: https://ecology.wa.gov/DOE/files/c8/c8a7577c-059a-4816-84ef-143e8faa5134.pdf

Ecology has a number of established partnerships to help inform the agricultural community about BMPs for protecting water quality across the state including: the Farmed Smart Certification Program, the Agriculture and Water Quality Advisory Committee, and the Voluntary Clean Water Guidance for Agriculture Advisory Group. These partnerships are intended to establish an inclusive process among a consortium of partners to minimize water quality impacts related to excess nutrients like nitrogen. Ecology's Voluntary Clean Water Guidance for Agriculture Advisory Group is in the process of developing BMP guidance on a variety of agricultural practices that promote healthy farms (i.e., sustaining production demands) and compliance with state water quality standards.

As of May 2021, new state legislation prohibits the regulation of ammonia emissions from use as agricultural or silvicultural fertilizer in Washington State (RCW 70A.15.4540[11]).

Runoff from forestry practices can be a concern, but primarily with respect to impacts on water temperature and sediment and their effects to downstream habitat for aquatic species such as salmonids. Ecology works with Washington's Department of Natural Resources to ensure that Forest Practices Board Rules meet state water quality standards to avoid significant contamination or degradation of water quality (Chapter 222-38 WAC[12]). Both the Forest Practices Rules and the Washington Watershed Restoration Initiative Program aim to protect aquatic habitats in or near forested areas and in-stream habitat.

4.1.2.2 Atmospheric Deposition

NH_3 gas is an important neutralizing base in the atmosphere and a precursor to wet/dissolved forms (NH_4^+), inorganic aerosols (i.e., ammonium-nitrate and ammonium-sulfate when in the presence of nitric and sulfuric acids), and fine particulate matter ($PM_{2.5}$ when in contact with dust, soot, smoke particulates) forms of atmospheric deposition. Dry and wet forms of deposition can have variable, but relatively short atmospheric lifetimes and can be transported near or far from the emission source influencing downstream or distant ecosystems with excessive nutrient inputs. While atmospheric transport of this pollutant is important, external influences are anticipated to be most influential from transboundary neighbors (i.e., Canada) and nearby states (e.g., Oregon, Idaho, Montana, and California).

Currently, point source gaseous emissions of NH_3 are not federally regulated under the CAA National Ambient Air Quality Standards (40 CFR part 50),[13] and recent Washington State legislation prohibits regulation of ammonia uses for fertilizer as stated above (RCW 70A.15.4540).[5] However, since gas-phase NH_3 can yield secondary fine $PM_{2.5}$, it technically could be regulated under the CAA (USDA 2014).

Although gaseous ammonia emissions are not regulated, the National Atmospheric Deposition Program (NADP) operates two national monitoring networks that measure wet and dry forms of deposition pertinent to tracking concentrations. Further, total deposition and ambient

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[11] Washington's state legislature can be found here: https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.15.4540

[12] Title 222 WAC Forest Practices Rules: https://www.dnr.wa.gov/publications/bc_rules_title222wac_032021.pdf

[13] 40 CFR part 50 can be found here: https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr50_main_02.tpl

concentrations of NH_4^+ have been monitored by the NADP- National Trends Network (NTN) since the late-1980s, which has demonstrated increasing NH_4^+ concentrations in many regions across the U.S.,[14] including in the midwestern and western states where agricultural operations (crops and livestock production) are highly concentrated. Monitoring of ambient gaseous NH_3 concentrations is also underway via the Ammonia Monitoring Network (AMoN),[14] but has much less extensive coverage in space and time relative to NTN. Currently, six NTN and two AmoN sites are in operation in Washington State providing limited spatial information about possible emission sources given their remote location. Ecology operates 55 sites across the state to monitor for local air quality pollutants, such as $PM_{2.5}$, but does not measure gaseous NH_3.

NH_3 budgets are still being refined with respect to certain emission sources (e.g., wildfires/ biomass burning, vehicles). However, it is known that agricultural practices (e.g., volatilization from fertilizer applications and livestock waste, as well as nutrient leaching into waterways), industrial and combustion sources, urbanization (e.g., NH_3 slip during catalytic reduction of NOx in vehicle fleets), and biological sources (e.g., soil emissions) all comprise important components of the budget (Fenn et al. 2003, Li et al. 2016, Sun et al. 2017, Fenn et al. 2018, Lindaas et al. 2021b). Regulation of gaseous NH_3 emissions are difficult due to measurement challenges related to volatility/stickiness of the gas, extent of monitoring program capability and data availability given measurement challenges, and the important role nitrogen has in growing food resources and supporting economic livelihoods. Atmospheric deposition or stormwater runoff containing products of atmospheric deposition pose negative implications for downstream aquatic habitat quality, as long as point source emissions remain unregulated and excessive nutrient applications (e.g., fertilizers) occur without effective implementation of BMPs.

4.2 Washington Water Quality

Under section 303(d) of the CWA, states and tribes are required to provide EPA a biennial list of waterbody segments that do not meet state WQS. Note that in many instances, Washington's existing chronic criteria for ammonia, rather than the acute criteria subject to this consultation, are used to establish the impaired waters list. On September 10, 2021, Ecology submitted its 2018 Integrated Report 303(d) list to EPA for approval and identified 14 freshwater waterbody assessment units as impaired for ammonia (~32.6 km in river segments) and 6 freshwater waterbody assessment units with ammonia-related TMDLs (21.6 km in-river segments; Table 4-1; WA-ECY, 2021). All impaired (Category 5) waters listings are primarily located in SE Washington along sections of the Middle-Lower Columbia River and northwest areas bordering Puget Sound, while listings with TMDLs in place (Category 4a) are primarily located in eastern and southwestern portions of the state (Figure 4-2). As discussed in detail above, many factors can cause elevated ammonia related to land-use practices and non-point source pollution as opposed to point-source discharges alone. Common actions that yield high ammonia include agricultural practices, such as the application of fertilizers for cultivated crops and waste streams from livestock operations requiring pasture/grasslands (i.e., CAFOs), which can supply localized and downstream ammonia pollution to waterways near and far from the source via runoff, nutrient leaching and atmospheric transport and/or eventual particulate formation. In addition, impacts of urbanization and population growth, such as vehicular emissions, urban fertilizer use

[14] Information about both NADP Monitoring Programs can be found here: http://nadp.slh.wisc.edu

and stormwater runoff can yield eventual excess ammonia runoff as well. With the exception of municipal or industrial stormwater runoff, these above inputs typically fall under non-point source pollution and are challenging to regulate under the CWA.

Table 4-1. Waterbody names, listing IDs, assessment unit extent (length, km or area, km^2) and category listing (4a or 5) from Ecology's 2018 draft 303(d) list. Information in this table corresponds to Figure 4-2.

Freshwater Waterbodies on Washington's 303(d) list for Ammonia-N (based on WA Ecology 2018 draft water quality assessmnt, April 2021)			
Waterbody (listing ID)	**Assessment Unit Extent (km/*km^2)**	**4a**	**5**
Deer Creek (8622)	0.598		X
Bertrand Creek (8629)	1.952		X
Fife Ditch (8678)	1.662		X
Paradise Creek (8826)	2.25		X
Medical Lake, West (8957)	0.833*		X
Swan Trail Slough (9298)	2.905		X
Cow Creek (40666)	13.818		X
WB5 Wasteway (71532)	4.054		X
PP 4.3 Wasteway (71547)	1.118		X
PP 66 Wasteway (71551)	1.48		X
Unnamed Canal - Trib to Columbia River (Wallula Lake) (71633)	1.625		X
Unnamed Creek - Trib to Samish Bay (71707)	0.148		X
Unnamed Creek - Trib to Edison Slough (71708)	0.463		X
Unnamed Creek -Trib to Alice Bay (71710)	0.555		X
Wildcat Creek (8739)	3.427	X	
Weaver (Woodin) Creek (8790)	1.801	X	
Mill Creek (8811)	10.011	X	
Pataha Creek (8828)	1.91	X	
Dragoon Creek (9049)	2.962	X	
Colville River (9065)	1.535	X	

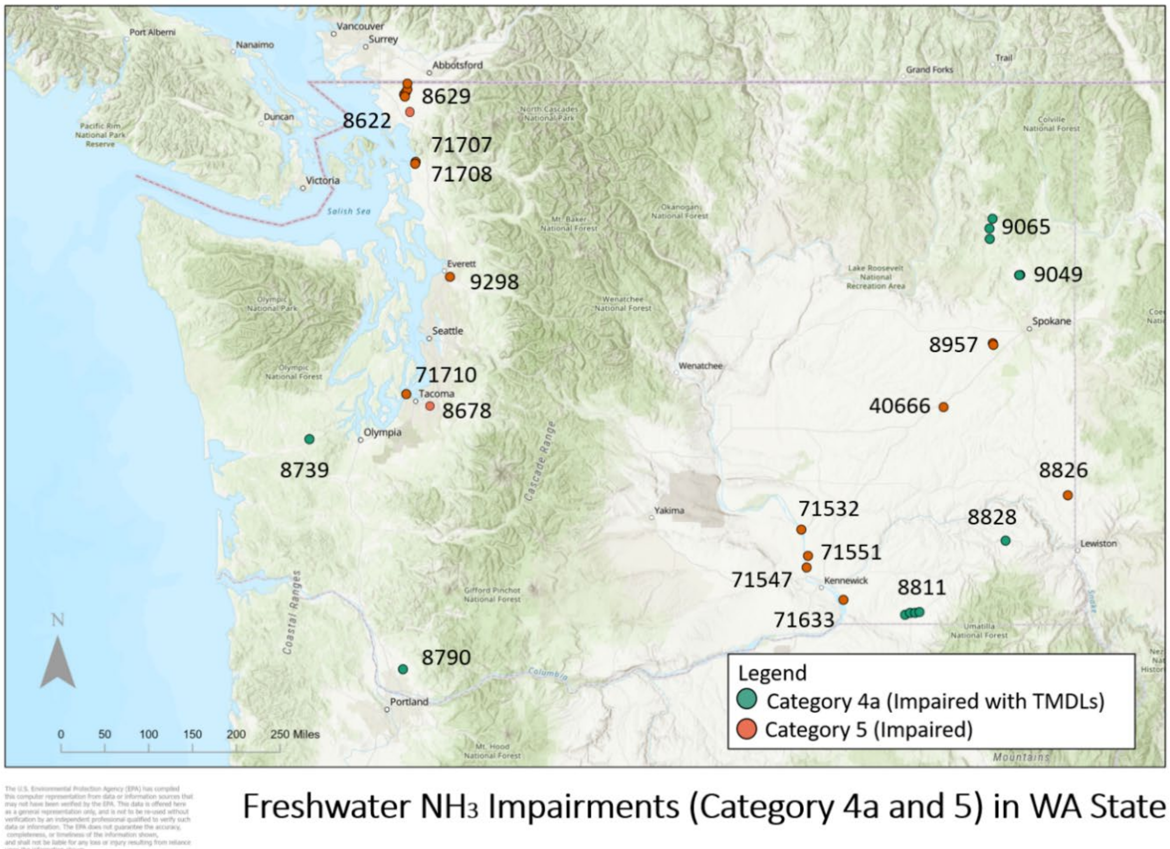

Figure 4-2. Map of freshwater impaired waterbodies across Washington based on Ecology's 2018 proposed 303(d) listings for ammonia-N. Numbers indicate the waterbody listing ID – additional information can be found in Table 4-1. The following listing IDs consist of multiple sampling locations and correspond to a single assessment unit within that waterbody: 8629 (Bertrand Creek), 8811 (Mill Creek), 8957 (Medical Lake, West), and 9065 (Colville River).

4.2.1 Effect of Surface Water Parameters on Ammonia Toxicity

Ammonia exists in two chemical forms (unionized NH_3 and ionized NH_4^+) in aquatic environments collectively referred to as total ammonia nitrogen (TAN = the sum of NH_3 and NH_4^+ concentrations), where the latter is more abundant and less toxic than unionized NH_3. The toxicity of TAN is dependent on the fraction of unionized NH_3 present relative to ionized NH_4^+, which is controlled by and increases with pH and temperature (Whitfield 1974, Emerson et al. 1975, Thurston et al. 1981c, Erickson 1985, Wood and Evans 1993, USEPA 2013). Within freshwater, TAN toxicity generally increases 10-fold with each pH unit increase (increasing H+ ion concentration equals a drop in pH) and 2-fold with every 10°C change from 0-30°C (Emerson et al. 1975, USEPA 2013). Based on this identified relationship, pH acts as a stronger control on toxicity relative to temperature because small changes in pH can result in large changes in unionized NH_3 concentrations (USEPA 2013). Analytical measurements typically are conducted on TAN, thus the fraction of TAN that is NH_3-only must be derived using the pH, T and pKa (equilibrium coefficient) – as described previously (Emerson et al. 1975, Wood and

Evans 1993). Consequently, comprehensive surface water measurements including pH, T, and TAN are necessary to conduct a complete analysis of potential ammonia toxicity and for deriving acute and chronic criteria for state water quality standards.

Additional considerations with respect to potential surface water controls on ammonia toxicity are related to respective land-use activities and the impact they have on temperature and pH, which are discussed in more detail in section 4.4.

4.2.2 Data Sources and Processing

Ambient water quality data were obtained and processed for freshwater sampling locations with concurrent pH, temperature (◦C) and TAN concentrations (N-mgL^{-1}) across Washington State between 2000-2020 from two primary databases and amounting to 39,184 records:

a) Department of Ecology's Environmental Information Management (EIM) Database: (https://apps.ecology.wa.gov/eim/search/default.aspx)

b) U.S. Geological Survey's National Water Inventory System (NWIS) Database: (https://nwis.waterdata.usgs.gov/usa/nwis/qwdata)

Geospatial information (consisting of either linear or polygon spatial data) was obtained from NMFS and USFWS for each species included within this baseline analysis. With the exception of eulachon, all species' designated critical habitat (DCH) included in this analysis are represented by polygons. Salmonid habitat consisted of two types of spatial information: species range (polygons) and DCH (lines). For salmonid ranges and DCH, the datasets (c-d) were used. All other NMFS and USFWS habitat datasets were accessed using (e-f):

c) Salmonid Species Ranges –West Coast Region Salmon and Steelhead Geodatabase 2015 (Ver. 1.0): https://www.fisheries.noaa.gov/resource/map/species-ranges-salmon-and-steelhead-all-west-coast

d) Salmon and Steelhead Critical Habitat: https://www.fisheries.noaa.gov/resource/map/critical-habitat-salmon-and-steelhead-all-west-coast

e) NMFS Species Critical Habitat: https://www.fisheries.noaa.gov/resources/maps?title=critical+habitat&tid%5B1000001126%5D=1000001126&field_species_vocab_target_id=&sort_by=created

f) USFWS Threatened and Endangered Species Active Critical Habitat Report: https://ecos.fws.gov/ecp/report/table/critical-habitat.html

Lastly, National Landcover/Land-Use data (2016 release) was obtained for Washington to assess the proportion of different landcover classifications that intersect with T/E species habitat from the Multi-Resolution Land Characteristics Consortium in an effort to understand possible land-use influences:

g) National Landcover Dataset (2016): https://www.mrlc.gov/data

4.2.2.1 pH

All pH records were filtered based on the WA state standard used in the presence of salmonids (6.5 to 9.0) (Freshwater Designated Uses and Criteria, WAC 173-201A-200 – Table 200 1g "Salmonid Habitat, Rearing and Migration"). For summary statistics presented below, the arithmetic average was calculated using the following formula: $[-log_{10}[\sum C_i/(n)]]$, where C_i refers to the concentration of hydronium ions, which can be derived from 10^{-pH}, and *n* refers to the sample number.

4.2.2.2 Temperature

All temperature data were filtered based on salmonid temperature thresholds (0-20˚C) with a 10˚C buffer, such that summary statistics are based on records within 0-30˚C and capture surface water temperatures based on *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* and Washington's Water Quality Standards numeric criteria for temperature ((USEPA 2003); WAC 173-201A-200 – Table 200 1c).[5]

4.2.2.3 Ammonia

All available pH and temperature records (39,184) sampled on the same date and at the same location were used to calculate TAN criteria as nitrogen in milligrams per liter (N-mg/L) to account for acute (CMC) conditions in the presence/absence of salmonids and how the criteria are implemented. Criteria values were calculated according to Washington State's Water Quality Standards (Toxic substances, WAC 173-201A-240 – Table 240)[15] and were also compared with ambient TAN concentrations at each surface water sampling location.

There are a few considerations to keep in mind regarding this component of the dataset. Of note, there is less extensive spatial coverage of in-situ TAN measurements compared to pH and temperature, providing a reduced perspective on freshwater TAN concentrations across the entire state. In addition, TAN can be quite challenging to measure due to its instability in the environment (e.g., volatilization/reactivity, easily transformed if in presence of microbial nitrifying bacteria), and respective controls of pH and temperature on the unionized ammonia fraction such as during sample storage prior to measurement that may lead to inadequate reflections of concentrations within the environment at the time of collection if done without careful processing (i.e., filtering for bacteria/chemical additives and pH/temperature storage controls). Data at the reporting or detection limit was included in the analysis, and thus baseline results should be interpreted as a conservative assessment.

4.2.2.4 Filtering and Joining pH, T, and ammonia datasets

In-situ ambient measurements were included in this analysis after these data reduction and joining steps. Note that these steps were determined in coordination with Ecology given the state's familiarity of EIM and the data it contains.

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[15] The Washington TAN criteria calculator can be found here; https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-quality-standards/Criteria

- Only used StudyIDs in which the quality assurance (QA) planning level was ≥ 3 and the QA assessment level was ≥ 3
    - QA planning level:
        - 3 = QAPP, SAP, or Equivalent
        - 4 = Approved QAPP or SAP
    - QA assessment level
        - 3 = Data Verified and Assessed for Usability
        - 4 = Data Verified and Assessed for Usability in a Formal Study Report
        - 5 = Data Verified and Assessed for Usability in a Peer-Reviewed Study Report
- Ammonia parameters: Ammonia, Ammonia as NH_3, Ammonia as N
    - If Parameter = Ammonia, only used records from Manchester Environmental Labs
- Only used discrete temperature and pH data
    - Only used pH data within 6.5-9.0
    - Only used temperature data within 0.0-29.99 °C
- Used all fraction types (dissolved, blank, total) but just total fraction for ammonia.
- TAN concentration data that were less than the reporting limit or detection limit were assumed to be at the sample reporting limit in order to conduct a conservative baseline assessment (i.e., ammonia concentrations biased high).
- Ammonia concentration data were then joined with matching pH and T records by "Location_ID" and "Field_collection_start_date"
    - Field_collection_start_date was rounded down to the minute and records were then joined

4.2.2.5 Data Analysis

Both temporal and spatial trends were assessed to summarize this comprehensive dataset comprising surface water chemistry measurements and species location information across Washington State freshwaters.

Temporal trends in TAN concentrations and calculated acute TAN criteria were assessed to see whether changes have taken place before (2000-2008) and after (2009-2020) EPA's 2008 action with respect to the acute TAN criteria and ambient TAN concentrations using both box and whisker plots and cumulative distribution functions (CDF) (Figures: 4-3 – 4-4). CDF plots were used to illustrate potential differences between TAN and CMC concentrations in both time periods based on a calculated hazard quotient (i.e., ratio of TAN/CMC).

A series of spatial maps were produced using the surface water and geospatial species DCH and range datasets including: a) statewide sampling locations for all concurrent pH, temperature and TAN measurements and b) DCH and range (for NMFS managed salmonid species) maps organized by agency authority (USFWS and NMFS); Figures: 4-7 – 4-13). For USFWS and NMFS species, only water chemistry data from NWIS and EIM sampling locations that were within 100 meters of respective species DCH were included in the analysis and illustrated on the maps.

Summary statistics are presented for the entire state and by species habitat for the following parameters (pH, T, TAN, CMC) as box and whisker plots, density distributions and tables

(Figures: 4-5 – 4-6, 4-14 – 4-17; Tables: 4-2 – 4-5). Statistical metrics include calculated means and medians for each parameter. Percentiles (0^{th}, 10^{th}, 25^{th}, 50^{th}. 75^{th}, 90^{th}, 100^{th}) were calculated for ambient surface water TAN concentrations. All data are organized by agency authority (USFWS and NMFS) and ESU/DPS code. Surface water TAN concentrations are presented using a log-scale. Certain DPS/ESU populations were not within 100 meters of water chemistry measurements. These DPS/ESUs are noted in figure captions where chemistry measurements were not present due to limitations of data availability/spatial coverage. Additionally, a few ESUs had ranges outside of the action area (e.g., STUW, CKUW, SOSR), thus only data available for DCH within the action area was considered in the analysis.

To investigate possible land-use influences on species that may impact ambient TAN surface water concentrations, the proportion of each landcover classification/land-use type was calculated relative to the total habitat area for each species and the National Landcover Dataset for the state using intersect analysis (Table 4-6). Landcover classifications mapped across the state include forested (evergreen, deciduous and mixed forest types) and unforested landcover types including: shrub/scrub, herbaceous, agriculture (hay/pasture, cultivated crops), wetlands (woody and emergent), perennial snow/ice, urban (developed, open-high intensity), barren lands, water and unclassified (Figure 4-18).

Finally, species habitat spatial proximity to permittees with established ammonia limits and/or monitoring, waterbody assessment units impaired for ammonia and waterbody assessment units with active Total Maximum Daily Loads (TMDLs) were assessed where all facilities or assessment units within 100 meters of habitat were summarized (Table 4-7). Ecology is currently undergoing review and submission of a multi-year integrated report, therefore the list of assessment units with impairments and/or TMDLs corresponding to ammonia in fresh surface waterbodies across the state accounted for in this analysis are from the proposed draft list for the 2018 Integrated Report. Results from both analyses are presented in sections 4.4 and 4.5, respectively.

4.2.3 Spatiotemporal Variation of pH, Temperature, and NH3

Across Washington state surface waters, ammonia concentrations and calculated acute ammonia criteria exhibit similar trends before and after EPA's 2008 action (Figure 4-3). Similarly, cumulative distribution plots illustrate similarities between hazard quotients in both time periods, however a higher proportion of low hazard quotient values are evident in 2000-2008 (Figure 4-4). Given these similar temporal trends pre- and post- action and overall data availability for ambient TAN concentrations, the remaining analytical summary is presented using the entire 20-year dataset with respect to water chemistry and species habitat.

For species that reside in estuarine/marine waters, but consume freshwater prey, only surface water data used by the species potential prey are presented. For example, the focal point of analysis for southern resident killer whale are salmonid species (i.e., primary prey source) and representative ambient and acute conditions in salmonid habitat (DCH and range).

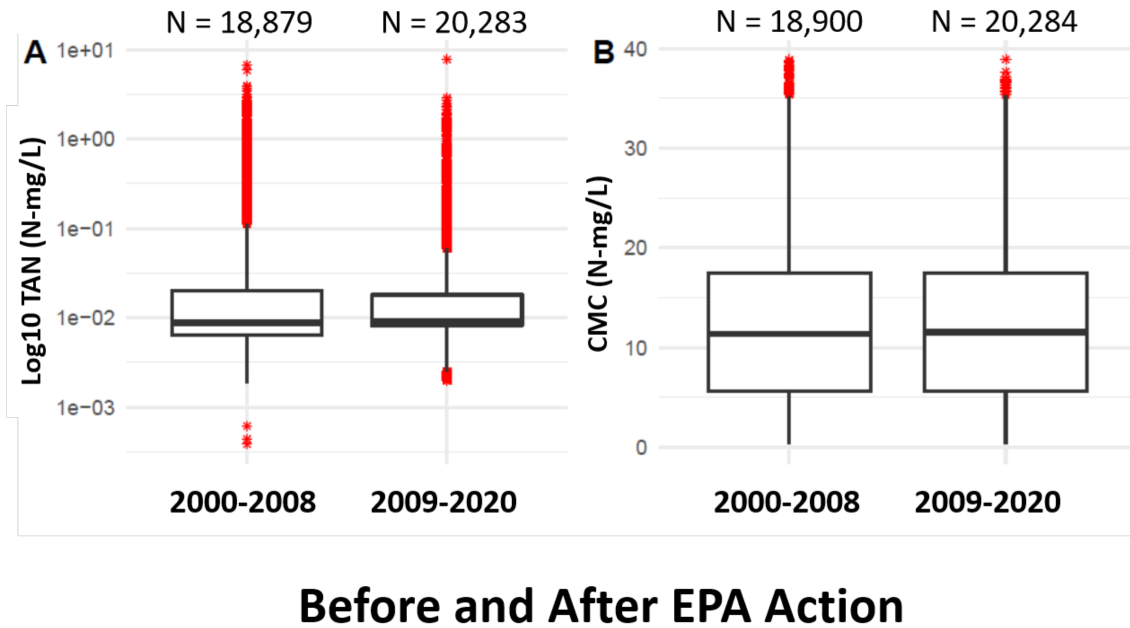

Figure 4-3. WA surface water (A) TAN concentrations (TAN – N in mg/L) and(B) acute TAN criteria (CMC, N-mg/L) before (2000-2008) and after (2009-2020) EPA 2008 action. Boxplot summary statistics include: the minimum and maximum values (black whiskers), the interquartile range (25th and 75th as boxes) and the median (thick black bar between interquartile boxes). Outliers are presented as red diamonds. Surface water sample size is reflected above each box and whisker plot. Note: TAN is on log-scale.

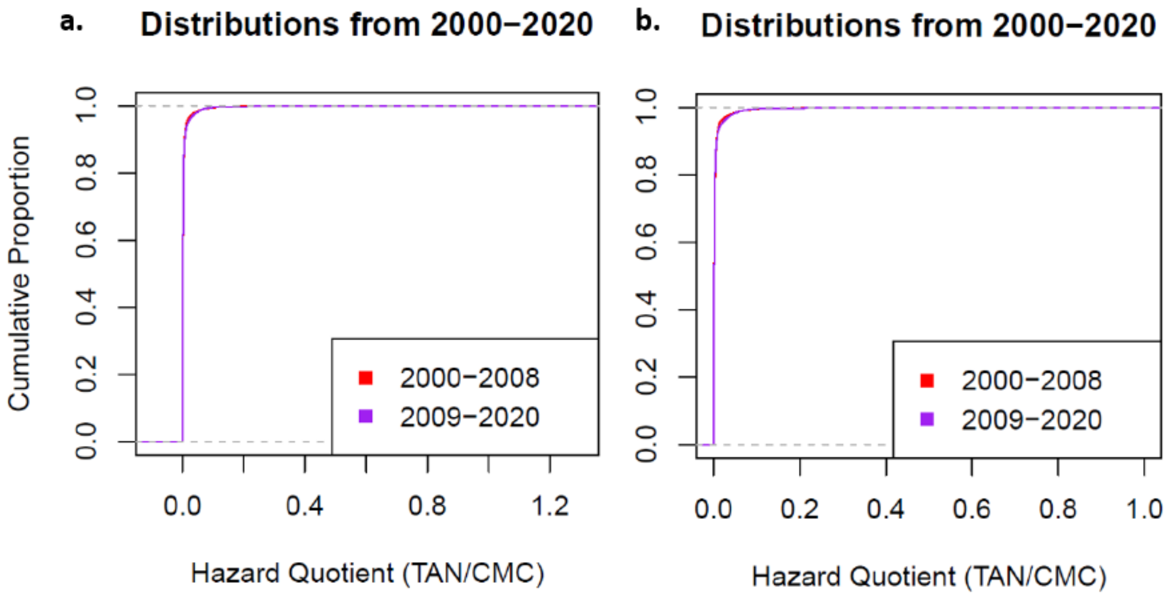

Figure 4-4 Cumulative distribution function (CDF) illustrating the hazard quotient or the ratio of TAN as nitrogen (TAN – N in mg/L) relative to acute TAN criteria (CMC, N-mg/L) as a cumulative proportion (y-axis) before (2000-2008, red line) and after (2009-2020, purple line) EPA action. Grey dashed lines delineate where the cumulative proportion equals 0 and 1. Panel (b) condenses the scale in Panel (a) from 0-1.

4.2.3.1 Statewide Temperature, pH, NH_3 variation

Statewide average and median surface water temperatures, with respect to the species habitat of concern for this biological evaluation, broadly reflect the middle of the salmonid tolerance range (~10.5-11 °C) and alkaline pH values (7.4-7.6; Table 4-2; Figure 4-5). TAN concentrations reflect low and on average near/below detection limits of standardized methods (<0.05-0.1 TAN – N as mg/L), and well below calculated acute TAN criteria (11.4-12.3 TAN-N as mg/L) (Table 4-2; Figure 4-6).

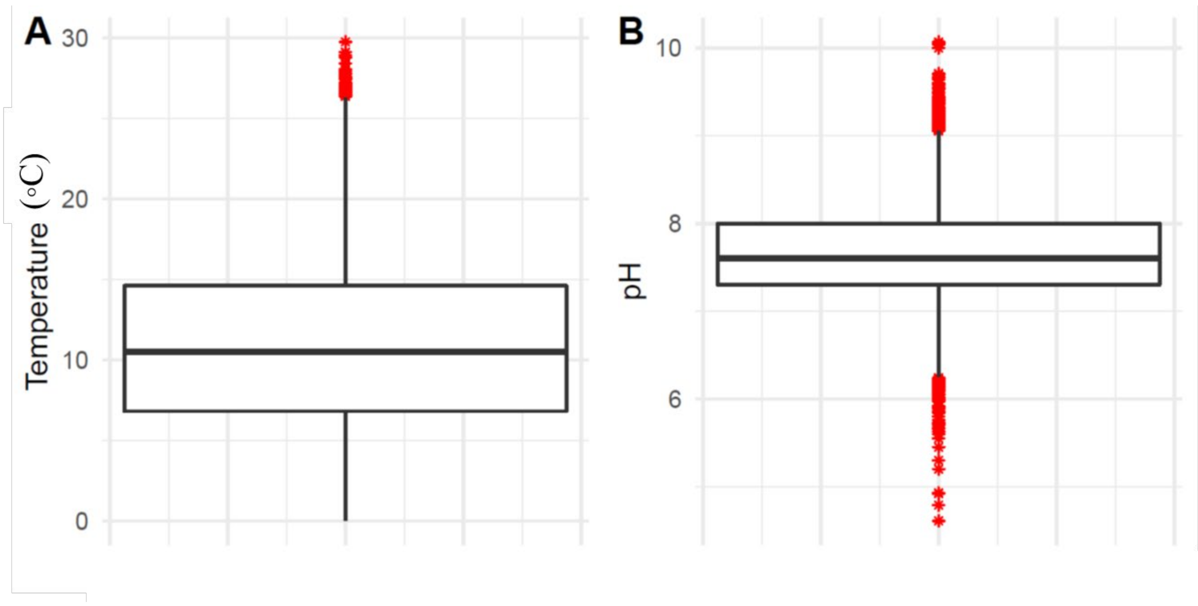

Figure 4-5. WA surface water (A) temperature (°C) and (B) pH spanning 2000-2020. Boxplot summary statistics include: the minimum and maximum values (black whiskers), the interquartile range (25th and 75th as boxes) and the median (thick black bar between interquartile boxes). Outliers are presented as red diamonds. Surface water samples reflected (n=39,184).

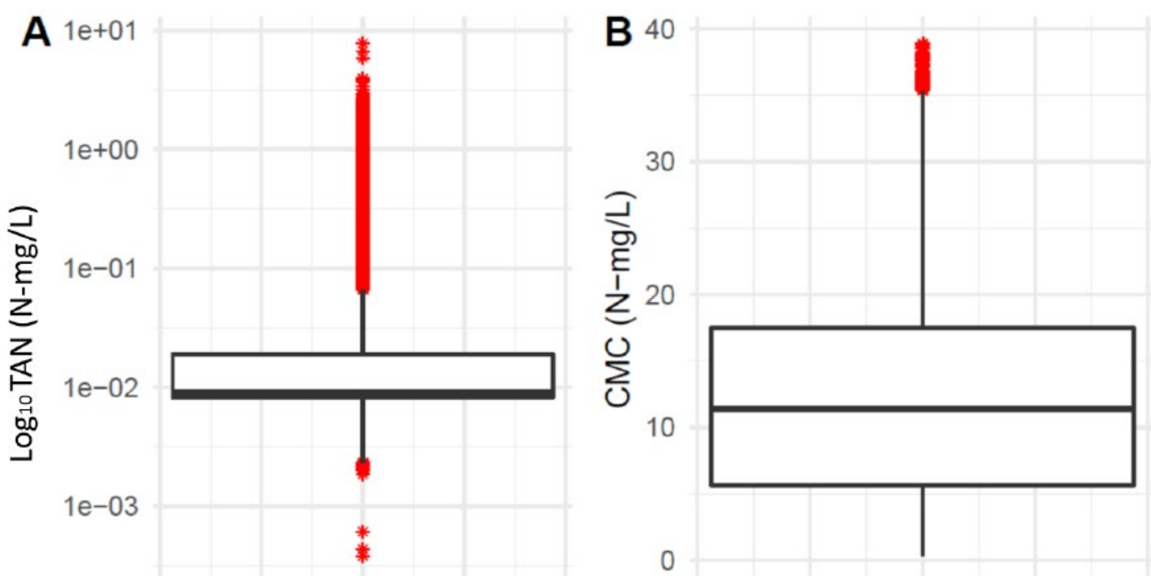

Figure 4-6. WA surface water TAN concentrations (TAN – N in mg/L) and calculated acute TAN criteria (CMC as N-mg/L) spanning 2000-2020. Boxplot summary statistics include: the minimum and maximum values (black whiskers), the interquartile range (25th and 75th as boxes) and the median (thick black bar between interquartile boxes). Outliers are presented as red diamonds. Surface water samples reflected (n=39,162 and 39,184 for TAN and CMC, respectively). Note: Panel (A) is on a log scale.

Table 4-2. WA State summary statistics (mean and median) for sampling locations where temperature (°C), pH and TAN in-situ measurements co-occur as well as associated calculated acute TAN criteria (CMC) values.

Parameter	Mean	Median
Temperature (◦C)	11.00	10.50
pH	7.40	7.60
TAN (N-mg/L)	0.03	0.01
CMC (N-mg/L)	12.30	11.40

4.2.3.2 Spatial Coverage of Species Critical Habitat

For all remaining figures and tables, T/E species Designated Population Segments (DPS) and Evolutionarily Significant Units (ESU) habitat (DCH for all species, range + DCH for salmonids only) are identified using four-letter codes (see Table 4-3). The spatial distribution of surface water sampling locations with concurrent chemistry measurements relative to T/E species habitat from 2000-2020 are illustrated in Figures 4-7 – 4-13.

Spatial coverage and overall data availability for concurrent ambient TAN, pH and temperature measurements were more limited with respect to all T/E species habitat except for salmonid species, primarily Chinook, steelhead, coho and chum, which encompass large portions of the statewide action area (Figure 4-7 – 4-13).

Table 4-3. ESA species information, including name, Distinct Population Segment (DPS) or Evolutionarily Significant Unit (ESU), and associated four-letter codes used as short-hand for all species

Species Name	DPS/ESU	Code
Marbled murrelet (*Brachyramphus marmoratus*)		MAMU
Oregon spotted frog (*Rana pretiosa*)		ORSF
Bull trout (*Salvelinus confluentus*)		BUTR
Green sturgeon (*Acipenser medirostris*)	Southern DPS	GRST*
Eulachon (*Thaleichthys pacificus*)	Southern DPS	EULA
Southern resident killer whale (*Orcinus Orca*)	Southern Resident	ORCA*
Coho salmon (*Oncorhynchus kisutch*)	Lower Columbia River	COLC

Species Name	DPS/ESU	Code
Chum salmon (*Oncorhynchus keta*)	Columbia River	CHCR
	Hood Canal, summer	CHHC
Chinook salmon (*Oncorhynchus tshawytscha*)	Upper Columbia River, spring-run	CKUC
	Snake River spring/summer-run	CKSS
	Snake River fall-run	CKSF
	Upper Willamette River	CKUW*
	Puget Sound	CKPS
	Lower Columbia River	CKLC
Sockeye salmon (*Oncorhynchus nerka*)	Snake River	SOSR
	Ozette Lake	SOOL*
Steelhead (*Oncorhynchus mykiss*)	Upper Columbia River	STUC
	Snake River Basin	STSR
	Middle Columbia River	STMC
	Upper Willamette River	STUW*
	Puget Sound	STPS
	Lower Columbia River	STLC

* Indicates species DCH/range where no surface water data were available within 100 meters.

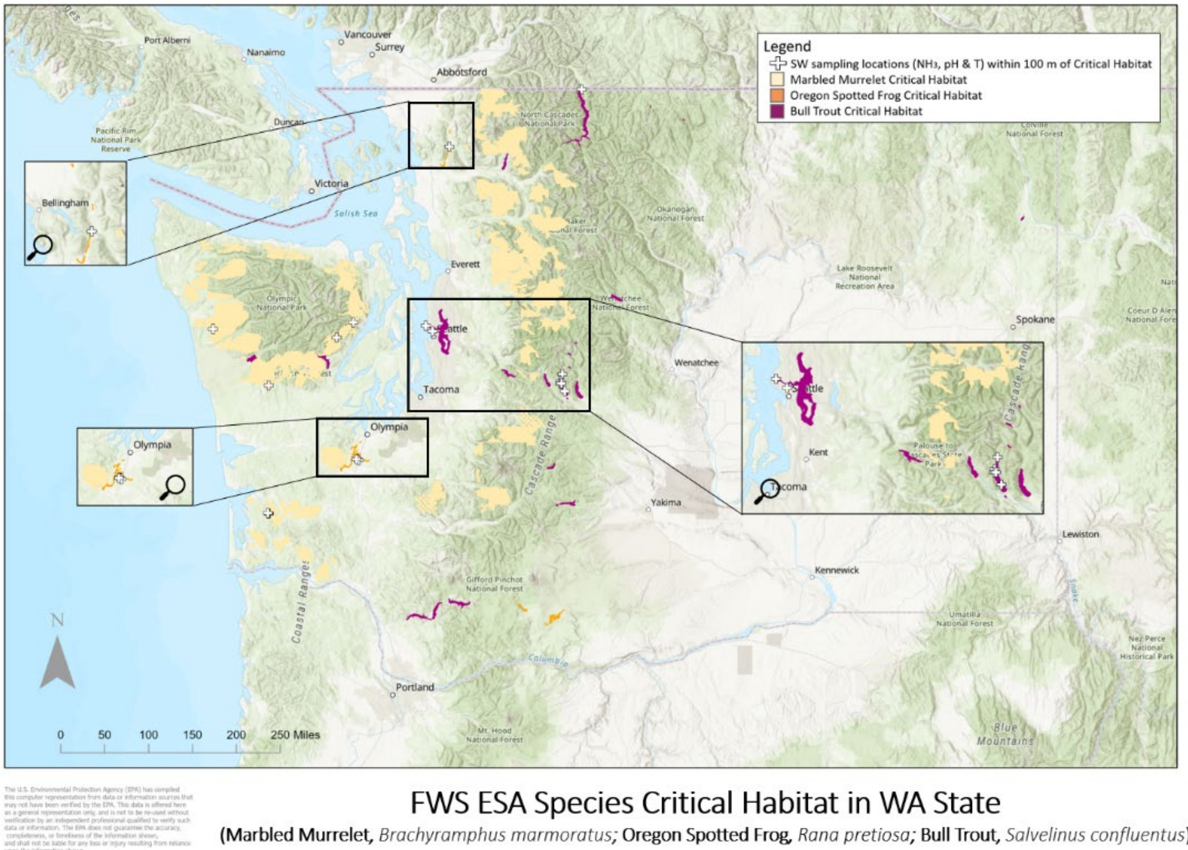

Figure 4-7. Map of surface water (SW) sampling locations (pH, T and TAN concentrations) within 100 meters of USFWS listed species habitat for marbled murrelet, Oregon spotted frog, and bull trout. Species designated critical habitat (DCH) is represented by polygons, which are colored by species. Magnifying glass icons reflect zoomed-in insets of the habitat.

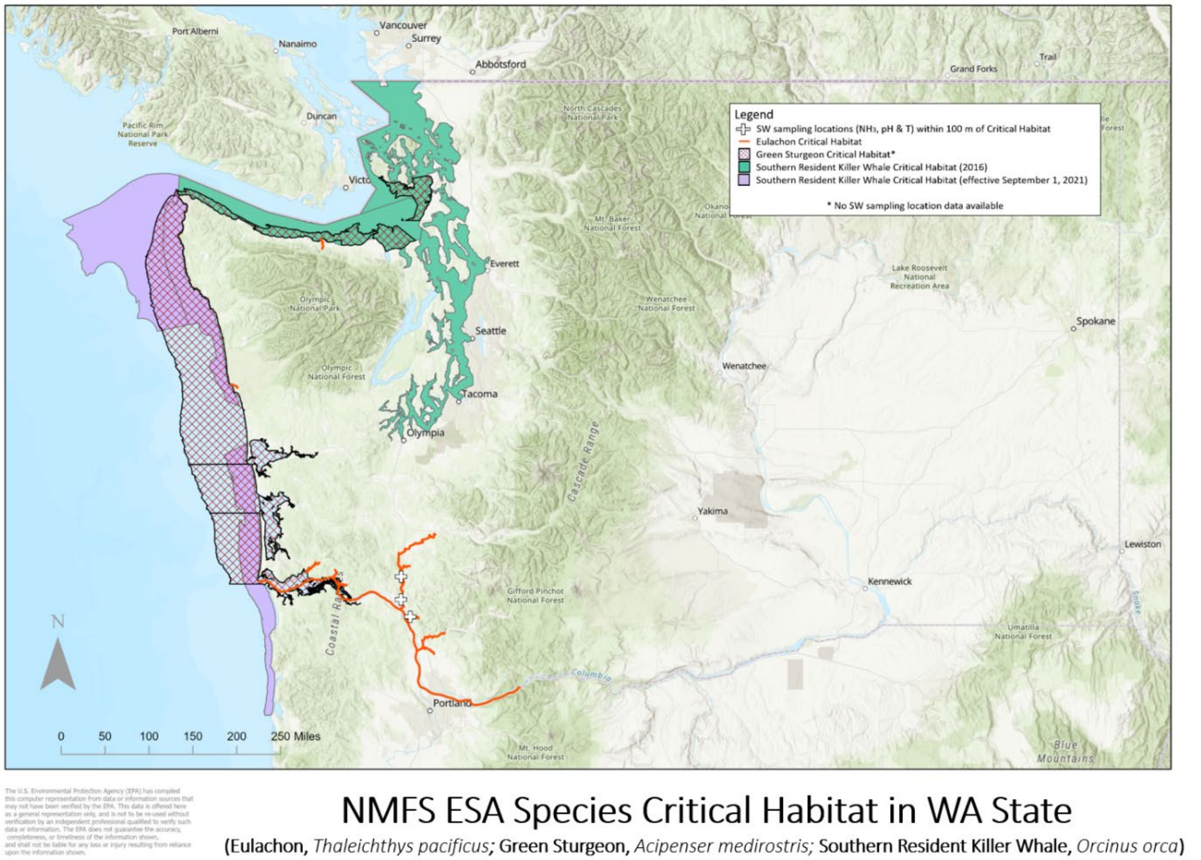

Figure 4-8. Map of surface water (SW) sampling locations (pH, T and TAN concentrations) within 100 meters of NMFS species designated critical habitat (DCH) for distinct population segments (DPSs): eulachon, green sturgeon, and southern resident killer whale (2016 and final 2021). DCH is color-coded by species and represented by polygons or lines.

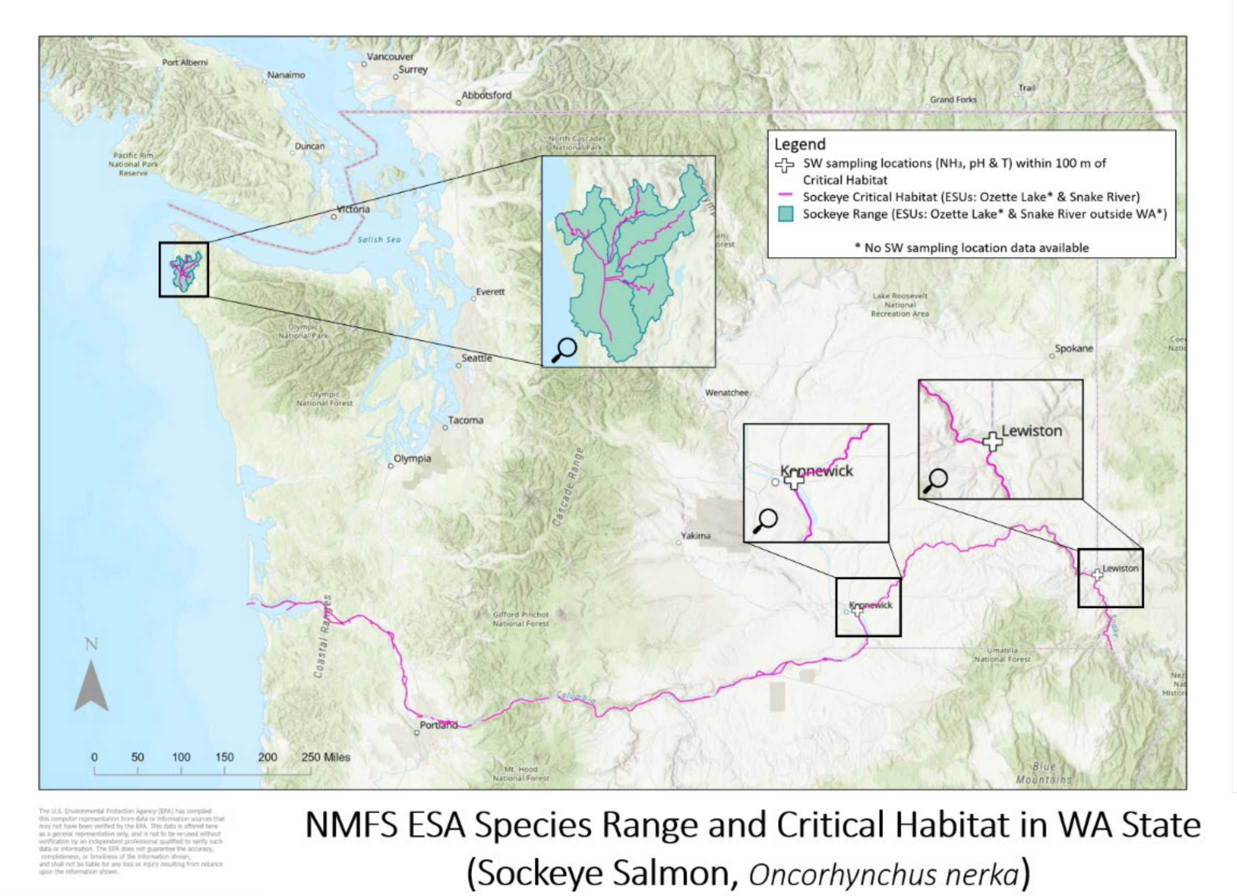

Figure 4-9. Map of surface water (SW) sampling locations (pH, T and TAN concentrations) within 100 meters of NMFS species habitat for sockeye salmon evolutionary significant units (ESUs: Ozette Lake and Snake River). Species range is represented by polygons (green), while designated critical habitat (DCH) is represented by lines (pink). The range for Snake River is outside the action area (WA State). Magnifying glass icons reflect zoomed-in insets of the habitat.

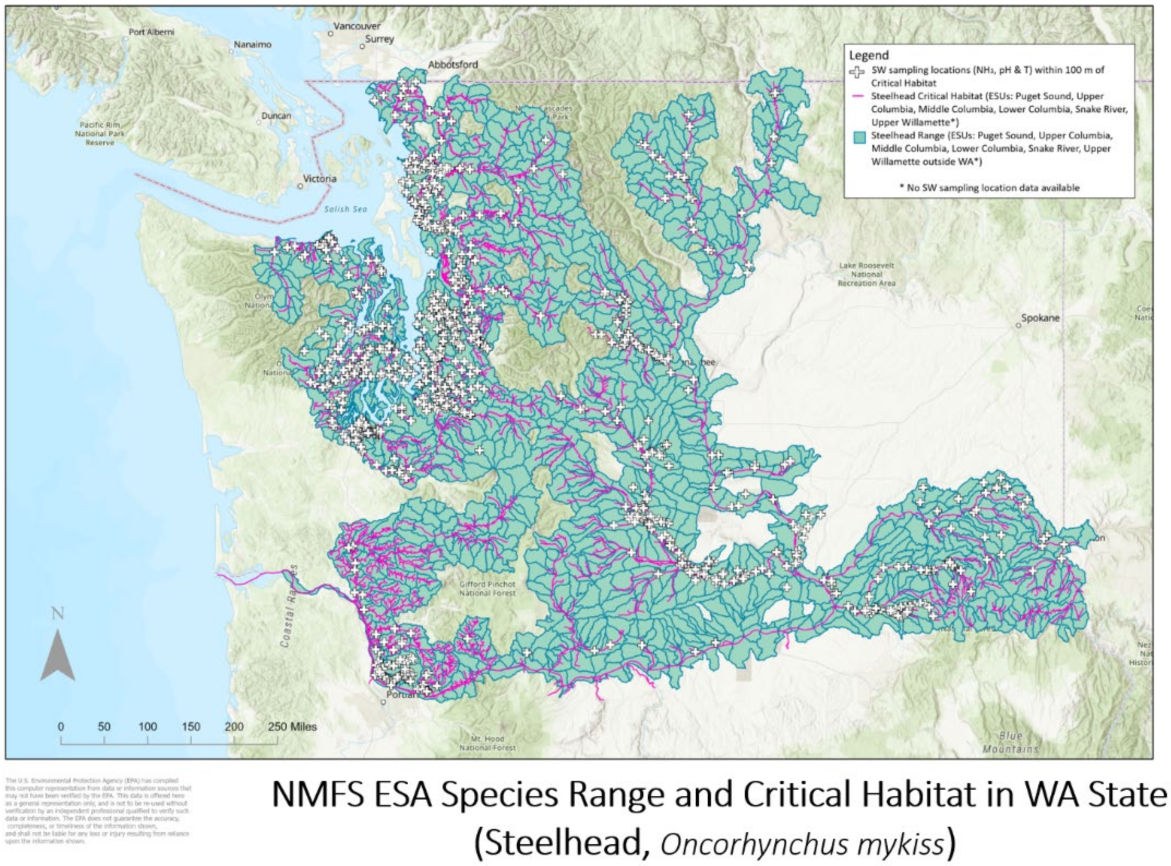

Figure 4-10. Map of surface water (SW) sampling locations (pH, T, and TAN concentrations) within 100 meters of NMFS species habitat for steelhead distinct population segments (DPSs) (Upper Columbia River, Snake River Basin, Middle Columbia River, Puget Sound, Upper Willamette River and Lower Columbia River). Species range is represented by polygons (green), while designated critical habitat (DCH) is represented by lines (pink). The range for evolutionary significant unit (ESU: Upper Willamette River) is outside the action area (WA State).

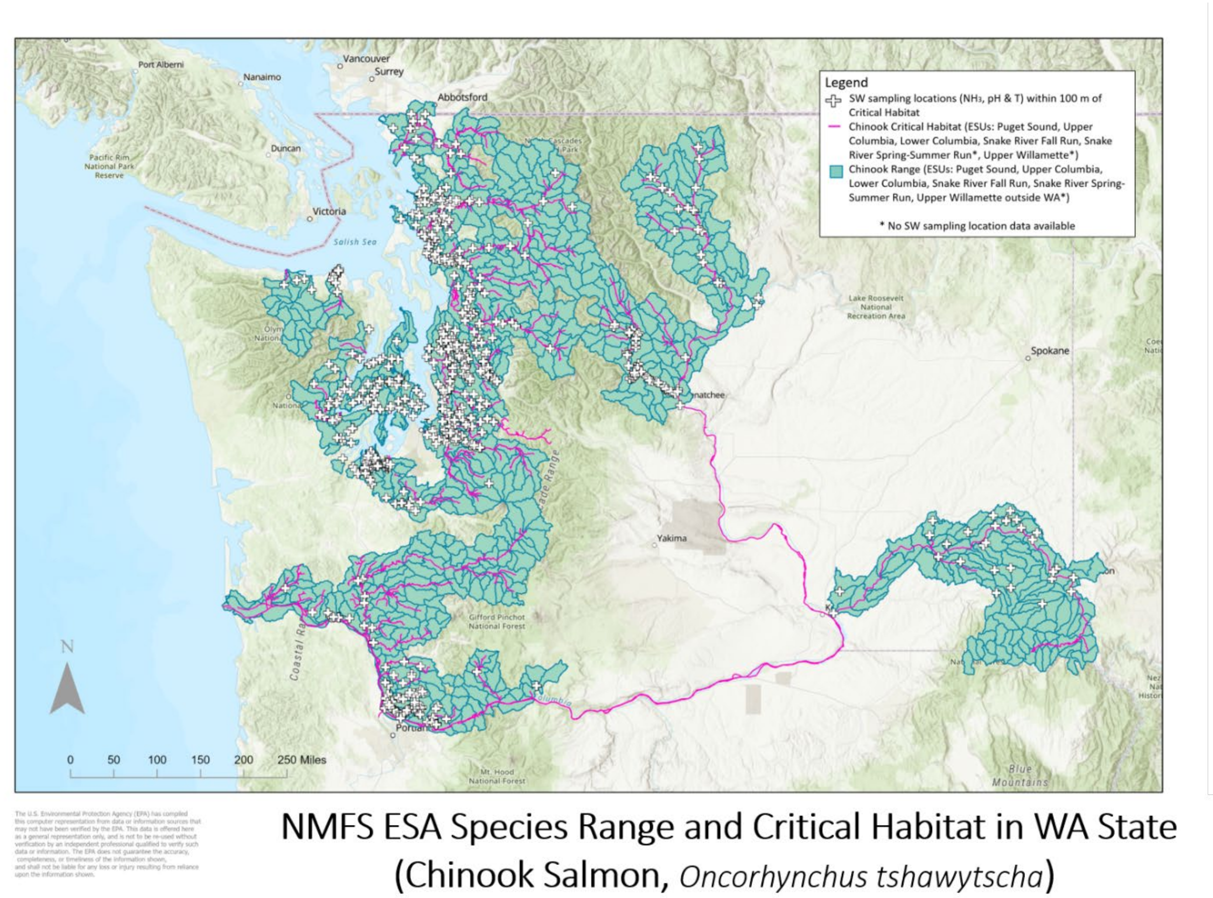

Figure 4-11. Map of surface water (SW) sampling locations (pH, T and total NH_3 concentrations) within 100 meters of NMFS species habitat for Chinook salmon evolutionary significant units (ESUs: Upper Columbia River – Spring Run, Snake River - Spring/Summer Run, Snake River – Fall Run, Upper Willamette River, Puget Sound and Lower Columbia River). Species range is represented by polygons (green), while designated critical habitat (DCH) is represented by lines (pink). The range for ESU (Upper Willamette River) is outside the action area (WA State).

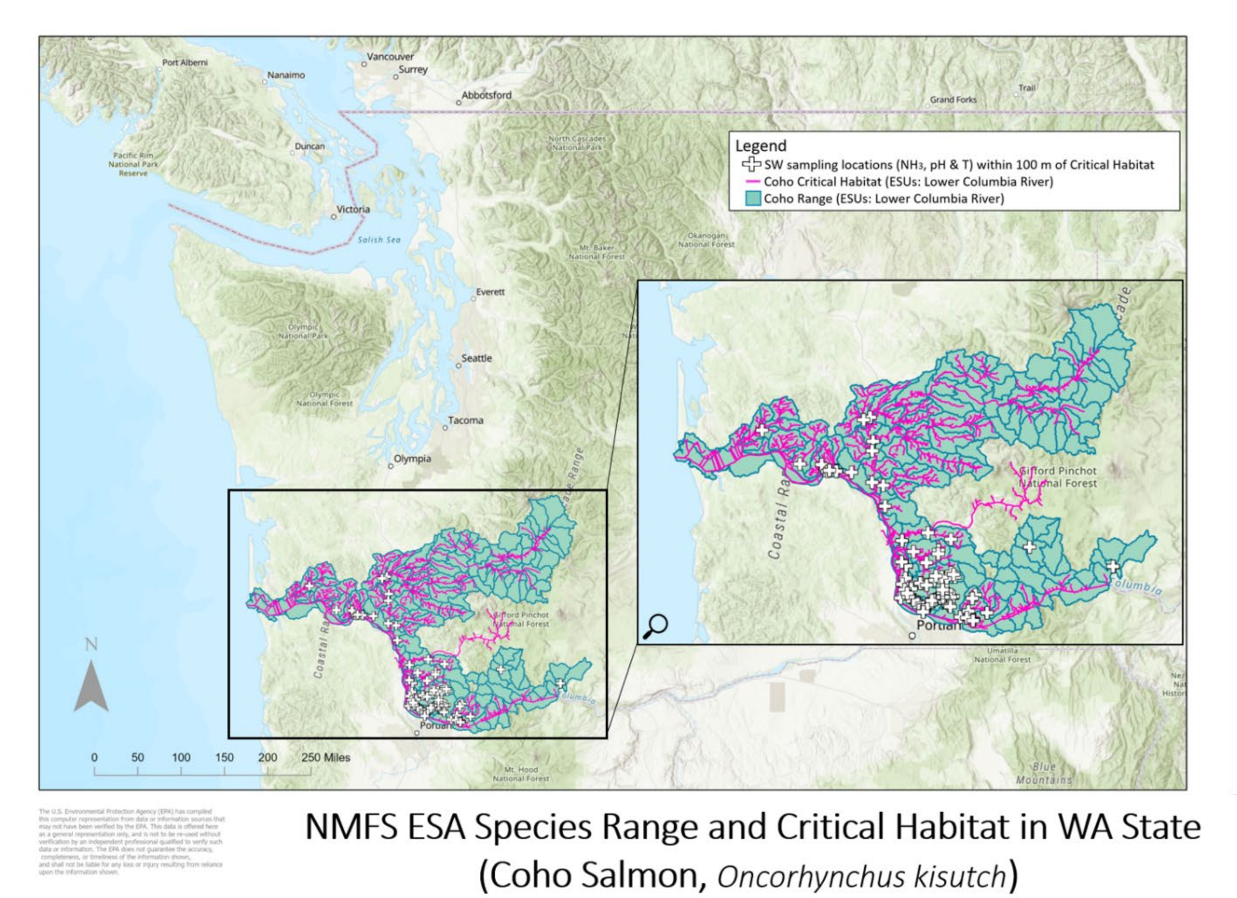

Figure 4-12. Map of surface water (SW) sampling locations (pH, T and total NH_3 concentrations) within 100 meters of NMFS species habitat for coho salmon evolutionary significant unit (ESU: Lower Columbia River). Species range is represented by polygons (green), while designated critical habitat (DCH) is represented by lines (pink). Magnifying glass icons reflect zoomed-in insets of the habitat.

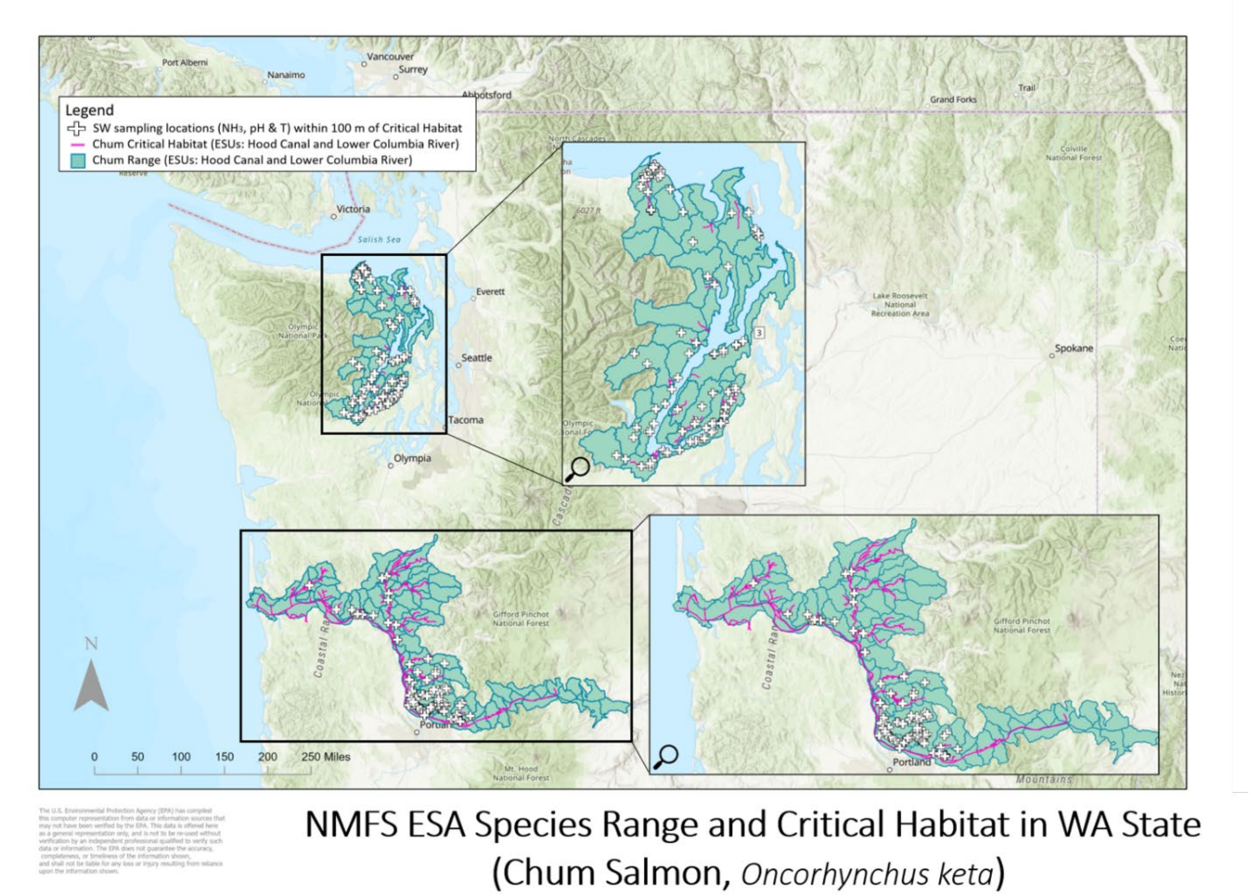

Figure 4-13. Map of surface water (SW) sampling locations (pH, T and total NH_3 concentrations) within 100 meters of NMFS species habitat for chum salmon evolutionary significant unit (ESUs: Columbia River and Hood Canal). Species range is represented by polygons (green), while designated critical habitat (DCH) is represented by lines (pink). Magnifying glass icons reflect zoomed-in insets of the habitat.

4.2.3.3 Temperature Relative to Species Habitat

High mean values (>10°C) correspond with all ESU/DPSs with the exception MAMU, CKUC, and CHHC habitat (Table 4-5). Surface water temperatures in bull trout habitat covered the largest and warmest range (IQR, 10-20 °C) compared to marbled murrelet (IQR, 5-10 °C) and Oregon spotted frog habitat (IQR, 7-15 °C) (Figure 4-14). Surface water temperatures covered a broad range of values with higher temperatures in bull trout waters (median = 14.9 °C; as high as 25 °C; Figures 4-14 and 4-15; Table 4-5). Temperature distributions for bull trout and Oregon spotted frog exhibited broad, multimodal distributions (multiple peaks) with three and two modes reflecting where large portions of the data fall within the distribution – e.g., temperatures at 20°C for bull trout, while temperature in marbled murrelet habitat appears fairly normally distributed (Figure 4-15). Within NMFS species habitat distributions often exhibit right-skewed, bimodal shapes with large ranges (20-30°C) centered between ~5-15°C (i.e., the interquartile range) (Figure 4-14 and 4-15).

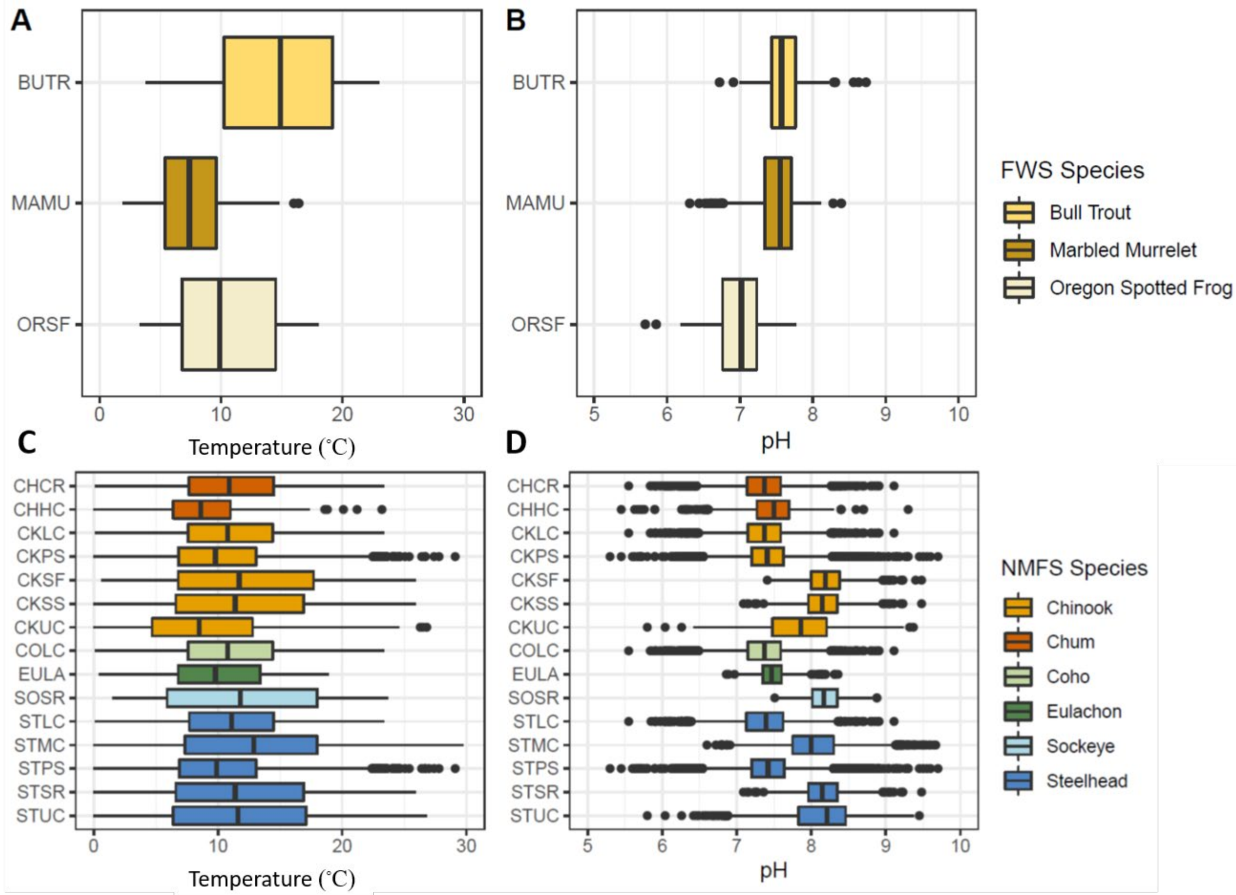

Figure 4-14. Surface water temperature (A, C) and pH (B, D) measurements in ESA species habitat (includes designated critical habitat (DCH) for all species; DCH and range for salmonids) across WA state (2000-2020). Species evolutionary significant unit (ESU)/distinct population segment (DPS) are identified by four letter codes and organized by agency authority: USFWS (A-B) and NMFS (C-D). Boxplot summary statistics include: the minimum and maximum values (black whiskers), the interquartile range (25th and 75th as boxes) and the median (thick black bar between interquartile boxes). Outliers are presented as black circles. No data available for CKUW, GRST, SOOL, and STUW. Species are identified by ESU/DPS codes from Table 4-3.

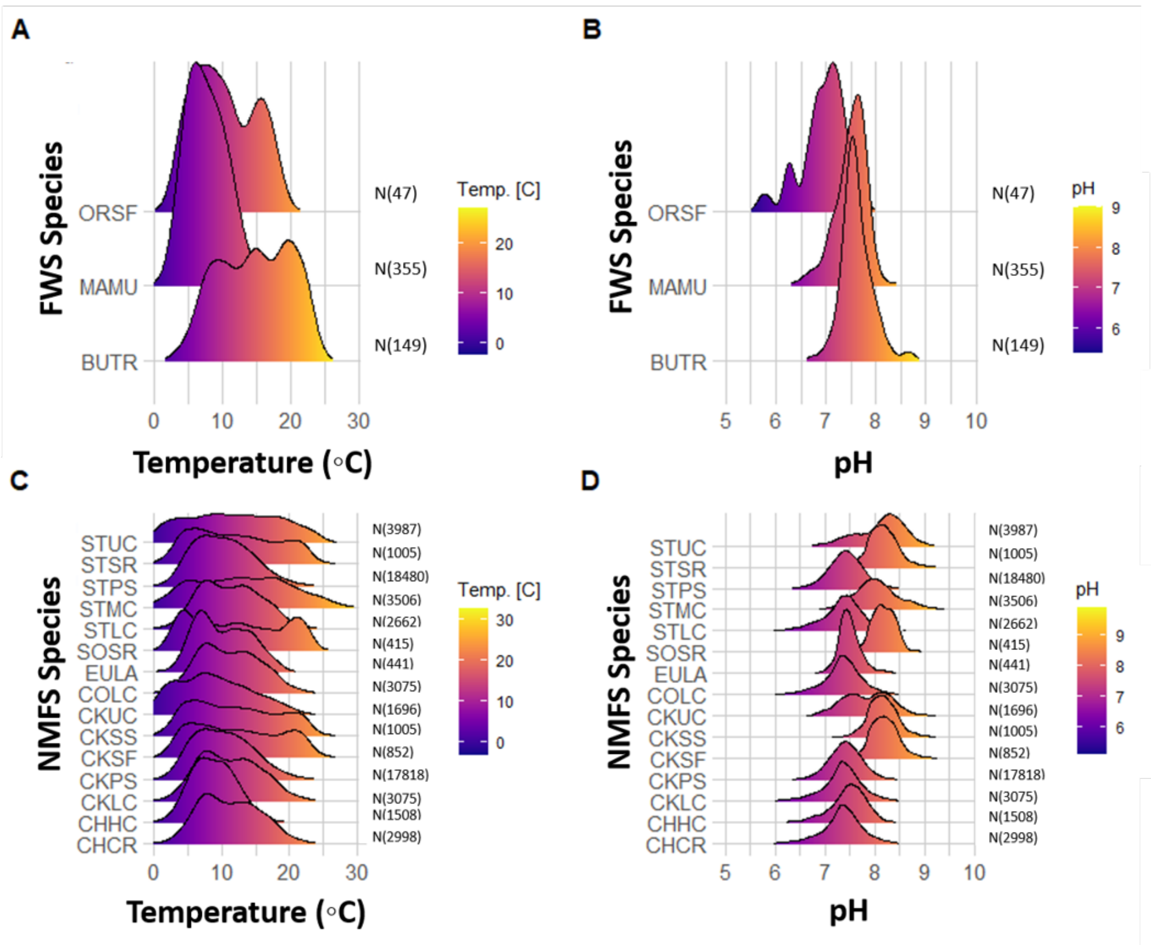

Figure 4-15. Density distributions of WA surface water sampling occurrences with (A, C) temperature and (B, D) pH in ESA listed USFWS and NMFS species habitat (includes designated critical habitat (DCH) for all species; DCH and range for salmonids) (2000-2020). Species evolutionary significant unit (ESU)/distinct population segment (DPS) are identified by four letter code and sample number (N) is identified next to each distribution. No data were available for the following ESU/DPS populations: GRST, SOOL, CKUW, STUW.

4.2.3.4 pH Relative to Species Habitat

Measured pH was slightly more alkaline (pH = 7.6) in bull trout and marbled murrelet habitat compared to Oregon spotted frog habitat (pH = 7; Figure 4-14, Table 4-5). Except for Oregon spotted frog, steelhead and Chinook Upper Columbia, surface water pH measurements illustrate unimodal, slightly left-skewed distributions inclusive of acidic and alkaline pH values (6-8.5) for most ESU/DPSs (Figure 4-14). Salmonid ESUs on the Upper and Middle Columbia River and Snake Rivers (STUC, STMC, STSR, SOSR, CKSS, SKSF) have slightly more alkaline pH ranges (7-9) (Figure 4-14). We note that acidic values (pH = 5.5-6) were observed in Oregon spotted frog habitat (Figure 4-15).

4.2.3.5 Ambient TAN Concentrations and Acute Criteria Relative to Species Habitat

Ambient TAN surface water concentrations are extremely low in all species habitat, where the majority of the dataset is below 0.1-0.2 mg/L for most species and largely below typical reporting or detection limits (e.g., 0.05-0.1 mg/L) (Table 4-4; Figure 4-16). For a few species (BUTR, CKPS, STMC STPC, STUC), concentrations reach as high as 1.39 to 7.77 mg/L, but largely fall below these values (Table 4-4; Figure 4-16). However, we note that these higher ambient values appear to be outliers across the dataset. Also of note, Oregon spotted frog DCH is an example where concentrations generally exceed 0.05/0.1 (N in mg/L) in the distribution, as well as, more variability across the range reflecting values within a detectable range relative to other species (Figures 4-16 and 4-17; Table 4-4).

In brief, ambient TAN concentrations are not comparable to acute TAN criteria values (Figure 4-16). Interestingly, Oregon spotted frog habitat, acute values were among the highest criteria values calculated in this dataset compared to other species (Table 4-5).

Acute TAN criteria values spanned a large distribution for all species (Figures 4-16 and 4-17; Table 4-5). Mean acute values ranged from 4.4 to 24.3 mg/L (Table 4-5). Surface waters pertinent for Oregon spotted frog habitat exhibited the highest interquartile range (IQR~20-30 N-mg/L) and mean acute value (24.3 mg/L), followed by Lower Columbia and Puget Sound based ESU/DPS, marbled murrelet and bull trout species (IQR~10-20 N-mg/L) and Middle and Upper Columbia and Snake River ESUs with the lowest range of acute TAN criteria values (IQR<10 N-mg/L; Figures 4-16 and 4-17). NMFS species with the lowest acute TAN criteria distributions were unimodal, narrow, and right-skewed, while the mid-ranging acute TAN criteria species exhibited broader, right-skewed distributions (Figure 4-17).

No surface water measurements were within range of the green sturgeon, steelhead and Chinook Upper Willamette, or sockeye Ozette Lake habitat for paired ambient TAN concentrations, temperature, and pH, thus no acute TAN criteria values are reflected in any of the summary figures beyond the habitat spatial distribution (Figures 4-8 and 4-11).

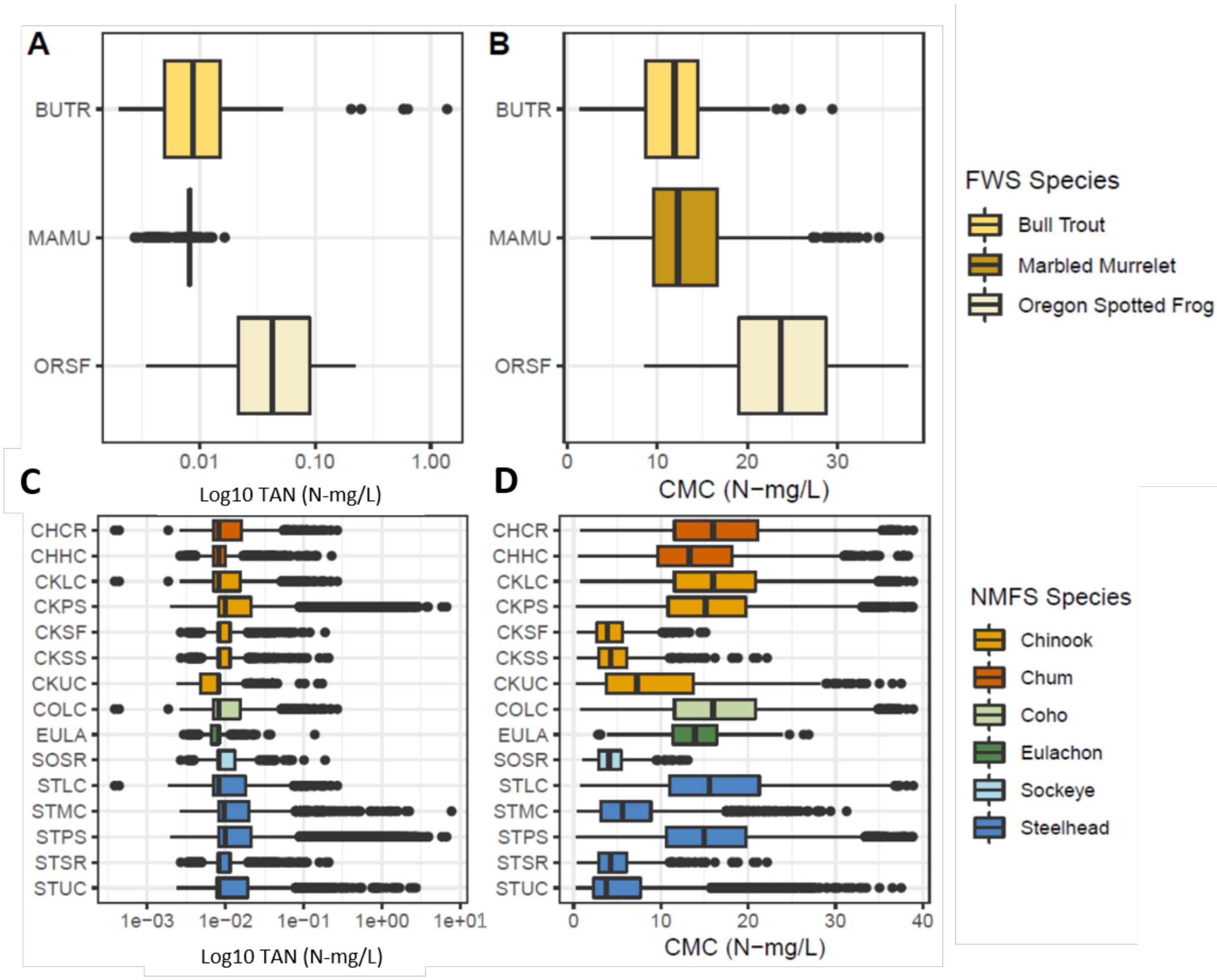

Figure 4-16. Surface water TAN concentrations (TAN, N-mg/L) (A, C) and acute TAN criteria (CMC, N-mg/L) (B, D) measurements in ESA species habitat (designated critical habitat (DCH) for all species; DCH and range for salmonids only) across WA state (2000-2020). Species evolutionary significant unit (ESU)/distinct population segment (DPS) are identified by four letter codes and organized by agency authority: USFWS (A-B) and NMFS (C-D). Boxplot summary statistics include: the minimum and maximum values (black whiskers), the interquartile range (25th and 75th as boxes) and the median (thick black bar between interquartile boxes). Outliers are presented as black circles. No data available for CKUW, GRST, SOOL, and STUW. Species are identified by DPS/ESU codes from Table 4-3.

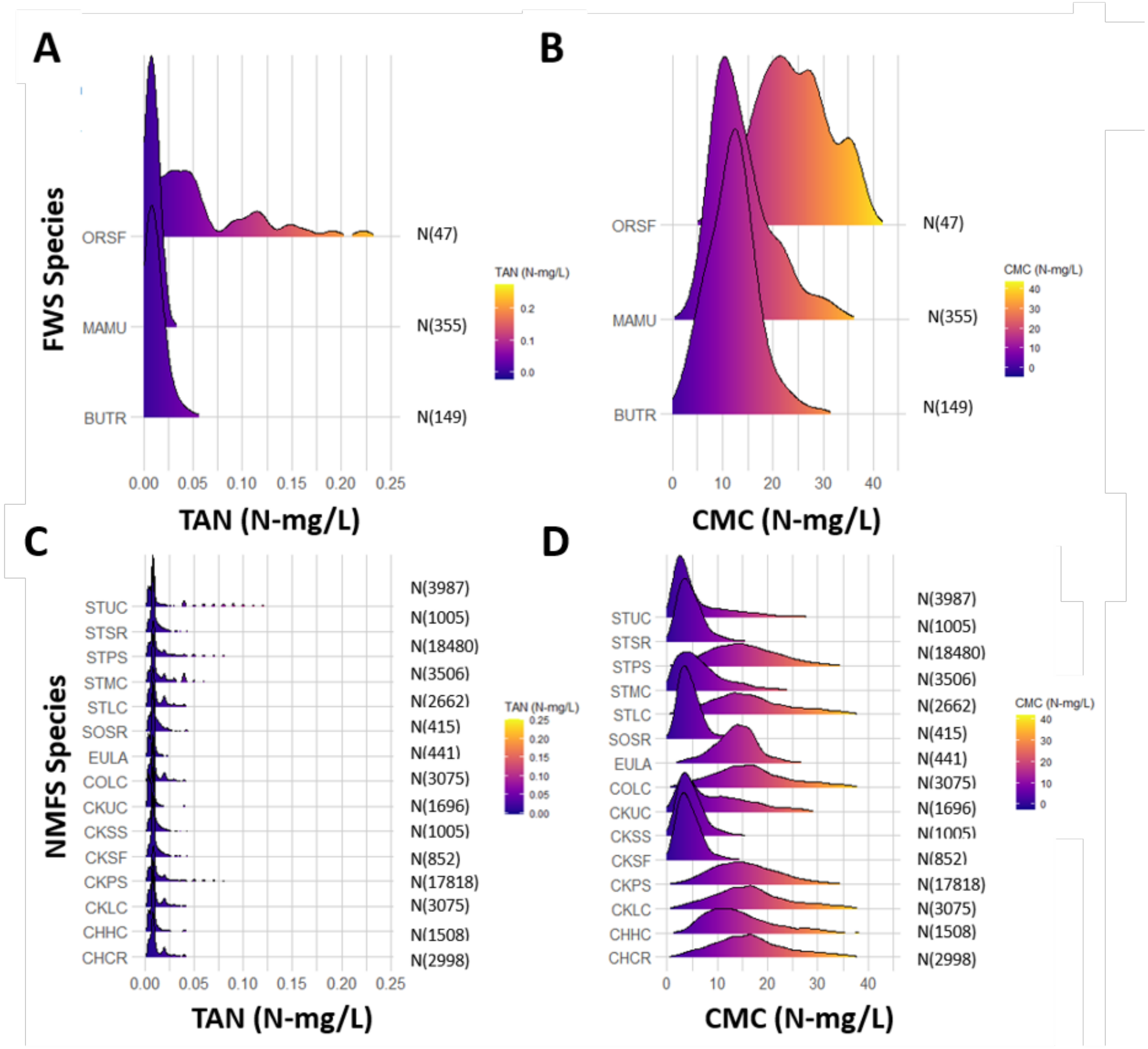

Figure 4-17. Density distributions of WA surface water sampling locations with (A, C) TAN concentrations (TAN, N – mg/L) and (B, D) acute TAN criteria (CMC, N-mg/L), in ESA listed USFWS and NMFS species habitat (designated critical habitat (DCH) for all species; DCH and range for salmonids only) (2000-2020). Species evolutionary significant unit (ESU)/distinct population segment (DPS) are identified by four letter code and sample number (N) is identified next to each distribution. No data were available for the following ESU/DPS populations: GRST, SOOL, CKUW, STUW.

Table 4-4. Percentiles for TAN concentrations by aquatic and aquatic-dependent species distinct population segment (DPS)/evolutionary significant unit (ESU) habitat (designated critical habitat (DCH) for all species; DCH and range for salmonids). Species are identified by DPS/ESU codes from Table 4-3 and organized by agency authority, where USFWS species comprise the top three rows followed by NMFS species.

	TAN Percentiles (N-mg/L)						
Species	**0%**	**10%**	**25%**	**50%**	**75%**	**90%**	**100%**
BUTR	0.0020000	0.0034000	0.0050000	0.0087000	0.0150000	0.0247000	1.3900000
MAMU	0.0027365	0.0043583	0.0082245	0.0082245	0.0082245	0.0082245	0.0164489
ORSF	0.0034339	0.0071531	0.0214470	0.0425726	0.0900126	0.1316311	0.2219521
CHCR	0.0003857	0.0045370	0.0070000	0.0082245	0.0160000	0.0272610	0.2700000
CHHC	0.0026404	0.0041539	0.0070636	0.0082245	0.0100000	0.0151915	0.2282690
CKLC	0.0003857	0.0046110	0.0070000	0.0082245	0.0154962	0.0269600	0.2700000
CKPS	0.0020000	0.0048720	0.0082245	0.0100000	0.0213836	0.0600000	6.7100000
CKSF	0.0026895	0.0055138	0.0082245	0.0082245	0.0115143	0.0189163	0.1883404
CKSS	0.0026895	0.0053447	0.0082245	0.0082245	0.0115035	0.0189163	0.2089015
CKUC	0.0024032	0.0037228	0.0048490	0.0082245	0.0082245	0.0101447	0.1733633
COLC	0.0003857	0.0046110	0.0070000	0.0082245	0.0154962	0.0269600	0.2700000
EULA	0.0029393	0.0038781	0.0065479	0.0082245	0.0082245	0.0106918	0.1389935
SOSR	0.0026895	0.0047962	0.0082245	0.0082245	0.0132539	0.0213836	0.1883404
STLC	0.0003857	0.0045931	0.0070000	0.0082245	0.0180000	0.0298379	0.2700000
STMC	0.0026718	0.0055701	0.0082245	0.0096202	0.0200000	0.0400000	7.7730000
STPS	0.0020000	0.0048999	0.0082245	0.0100000	0.0213836	0.0600000	6.7100000
STSR	0.0026895	0.0053447	0.0082245	0.0082245	0.0115035	0.0189163	0.2089015
STUC	0.0000000	0.0042161	0.0076927	0.0082245	0.0192452	0.0800000	2.7260000

Table 4-5. Summary statistics (mean and median) for temperature (°C), pH and calculated acute TAN criteria (CMC as N-mg/L) by aquatic and aquatic-dependent species distinct population segment (DPS)/evolutionary significant unit (ESU) habitat (designated critical habitat (DCH) for all species; DCH and range for salmonids). Species are identified by DPS/ESU codes identified in Table 4-3 and organized by agency authority, where USFWS species comprise the top three rows followed by NMFS species. Samples reflect the number of surface water records within habitat for generating summary statistics.

Species	Samples	Temperature (°C) Mean	Temperature (°C) Median	pH Mean	pH Median	CMC (N-mg/L) Mean	CMC (N-mg/L) Median
BUTR	149	14.7	14.9	7.5	7.6	11.9	11.9
MAMU	355	7.6	7.4	7.4	7.6	13.9	12.3
ORSF	47	10.2	9.9	6.7	7.0	24.3	23.7
CHCR	2998	11.2	10.9	7.1	7.4	16.7	16.0
CHHC	1508	8.8	8.6	7.2	7.5	14.5	13.3
CKLC	3075	11.1	10.8	7.1	7.4	16.7	16.0
CKPS	17818	10.1	9.8	7.3	7.4	15.6	15.1
CKSF	852	12.3	11.7	8.1	8.2	4.4	3.9
CKSS	1005	11.9	11.4	8.1	8.2	4.8	4.2
CKUC	1696	8.9	8.4	7.6	7.9	9.3	7.3
COLC	3075	11.1	10.8	7.1	7.4	16.7	16.0
EULA	441	10.2	9.8	7.4	7.5	13.7	13.9
SOSR	415	12.2	11.8	8.1	8.2	4.4	4.1
STLC	2662	11.3	11.1	7.1	7.4	16.5	15.6
STMC	3506	12.9	12.9	7.8	8.0	6.7	5.6
STPS	18480	10.2	9.9	7.3	7.4	15.4	14.9
STSR	1005	11.9	11.4	8.1	8.2	4.8	4.2
STUC	3987	11.7	11.6	7.8	8.2	6.1	3.8

4.3 Environmental Factors and Land Uses Affecting pH, Temperature, and Ammonia Concentrations

4.3.1 Land-Use Description across Washington State

Of the 43 million acres of land in Washington State, 21 million acres are forested and 22 million are unforested[16]. Of the forested land across the state, evergreen, deciduous and mixed forest types are present (Figure 4-18). Unforested landcover types consist of shrub/scrub, herbaceous, agriculture (hay/pasture and cultivated crops), wetlands (woody and emergent), perennial

[16] Washington Department of Natural Resources Washington's forests, timber supply and forest-related industries. https://www.dnr.wa.gov/publications/em_fwfeconomiclow1.pdf

snow/ice, urban developments (developed, open-high intensity), barren lands, water and unclassified (Figure 4-18). Shrub/scrub, herbaceous and cultivated crop landcover types largely make up the central-southeast corner of the state. Hay/pasture landcover is located to the east and west of the Cascades corridor, especially in areas north of Seattle (e.g., Skagit and Whatcom Counties), the northeast portion of the Olympic Peninsula (i.e., Clallam County), southwest (i.e., Clark County) and central (i.e., Kittitas/Yakima Counties) hotpots across the state (Figure 4-18). Areas containing urban/developed landcover of various intensity levels are located along the east to southeast side of Puget Sound (e.g., Seattle metropolitan area), in and around southwest Washington (near Vancouver and surrounding suburban developments, and in eastern portions of the state near Kennewick and Spokane (Figure 4-18).

Figure 4-18. Land-use/cover types across Washington State based on the National Landcover Dataset (NLCD, 2016).

4.3.2 Land-Use Relative to Species Habitat

Due to its vast spatial coverage, forested and scrub/shrub landcover types likely inhabit/intersect with large proportions of critical habitat for the following species: marbled murrelet and several salmonid ESUs (Table 4-6), where forested landcover comprises at least/greater than 50% of the coho, chum, chinook, sockeye and steelhead habitat (Table 4-6). Shrub/scrub, herbaceous and cultivated crops comprise the next largest proportions of landcover within range of salmonid critical habitat (Table 4-6), Where cultivated crops comprise as much as 30% of chinook (CKSS, CKSF) and steelhead (STUC, STMC, STSR) habitat that resides in the southeastern part of the state (Figure 4-18; Table 4-6). Wetland and hay/pasture landcover types are most prominent in Oregon Spotted Frog habitat (Table 4-6). Interestingly, all four categories of urban land-use/landcover comprise low (<10%) across all species habitat (Table 4-6), however urban development classified as having open space and low intensity occur in higher proportions of many salmonid ESUs relative to non-salmonid species (Table 4-6). Sturgeon habitat occurs within barren land, wetlands, and open water land covers primarily (Table 4-6). Bull trout, eulachon and green sturgeon habitat largely intersects with open water land-cover classifications with smaller proportions potentially influenced by forested, shrub/scrub and wetland landcover (Table 4-6). Open water (>90%) in the following ESUs (CKUW, STUW, EULA, and SOSR) is biased high because critical habitat spatial information used for the intersect analysis only involved line data. However, given the similarity in habitat coverage between CKUW, STUW and EULA with other species along the Lower Columbia River (e.g., COLC, CHCR, STLC, CKLC), the following land-uses (forested, scrub/shrub, hay/pasture and urban development – open space) likely have similar influences on these ESUs as well (Table 4-6). Similarly, the land-use types within which CKSS, CKSF and STSR occur also likely affect SOSR – namely shrub/scrub, herbaceous and cultivated crops (Table 4-6). No species had high proportions of habitat overlapping/intersecting with perennial snow/ice or medium-high urbanized landcover/uses (Table 4-6).

4.3.3 Additional Considerations Regarding Sources of Ammonia Relative to Land-Use

In areas containing cultivated crops, herbaceous, scrub/shrub and forested land-cover types where fertilizer applications may be and likely are utilized during important growing seasons, species habitat in proximity to these land-uses may incur nonpoint source inputs of ammonia from agricultural/silvicultural runoff. Similarly, hay/pastureland-use types typically associated with agricultural practices, such as concentrated agricultural feeding operations (e.g., dairies), have both direct and indirect ammonia waste streams. Agricultural (cultivated crops and hay/pasture) and urbanized land-uses comprise smaller proportions of habitat for most species compared to forested land. Yet, indirect/nonpoint source ammonia waste streams from agricultural and stormwater runoff will become more important with continual population growth/expansion and enhanced demand for food production without implementation of BMPs to minimize excess nutrient leaching/runoff. Further, increased frequency of extreme weather events (e.g., storms) will likely result in more nonpoint source runoff from localized sources, as well as, transboundary pollution sources discharged into U.S. watersheds (e.g., Bertrand Creek in Whatcom County, WA receives nitrogen pollution (among other pollutants) from upstream dischargers in British Columbia, Canada).

Table 4-6. Percent (%) of land-use/land-cover in Washington State that intersects with species critical habitat. Forest consists of deciduous (D), evergreen (E) and mixed (M) forest land-cover. Wetlands consists of woody (W) and emergent herbaceous (EH) wetland land-cover types. Dashes (-) indicate landcover types are unapplicable for a given species, whereas 0.0 indicates a very small percentage > 0.01 %. Highlighted cells indicate land-use percentages ≥ 5% within individual species evolutionary significant unit (ESU)/distinct population segment (DPS) habitat. Refer to Table 4-3 for species code references.

Percentage (%) of land-use/land cover that intersects species habitat in WA State

Species DPS/ESU	Unc	Open Water	Perennial Snow/Ice	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Forest (D,E,M)	Shrub/ Scrub	Herbaceuous	Hay/ Pasture	Cultivated Crops	Wetlands (W, EH)
MAMU	0.0	0.5	0.0	2.0	0.4	0.0	0.0	0.8	84.8	9.1	1.6	0.0	0.0	0.7
ORSF	-	0.8	-	1.6	0.6	0.0	0.0	0.0	5.8	3.0	1.9	13.1	0.9	72.4
BUTR	-	90.6	-	0.2	0.4	0.3	0.4	4.5	1.8	0.3	0.2	0.0	-	1.3
GRST	-	30.3	-	1.1	1.2	0.5	0.2	29.5	6.7	2.7	4.9	0.6	0.1	22.4
EULA	-	82.3	-	1.1	1.5	0.3	0.1	1.9	2.8	1.2	0.3	1.4	0.1	7.1
ORCA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
COLC	-	2.2	0.2	4.4	3.0	1.2	0.4	1.5	58.2	16.2	4.3	4.7	0.7	3.2
CHCR	-	2.6	-	5.7	3.9	1.6	0.5	1.7	48.1	17.9	5.8	6.9	1.0	4.3
CHHC	-	0.4	0.1	4.3	2.9	0.8	0.2	1.7	66.5	12.2	5.1	3.0	0.1	2.6
CKUC	-	1.2	0.1	0.8	1.6	0.5	0.1	2.5	48.1	28.7	11.4	1.6	2.4	1.0
CKSS	-	2.2	-	1.8	0.3	0.1	0.02	0.01	14.2	25.1	23.5	0.5	32.3	0.2
CKSF	-	3.5	-	1.7	0.4	0.1	0.0	0.0	4.2	34.8	22.0	0.6	32.4	0.2
CKUW	-	99.6	-	-	-	-	-	0.4	-	-	-	-	-	-
CKPS	-	1.3	1.1	5.3	5.6	2.5	0.9	2.9	57.8	11.2	3.7	4.2	1.0	2.6
CKLC	-	1.9	0.2	4.2	2.5	0.8	0.3	1.5	60.0	16.6	4.4	4.2	0.6	2.8
SOSR	-	98.6	-	0.2	0.2	0.2	0.03	0.2	0.0	0.1	0.05	0.04	-	0.3
SOOL	-	12.9	-	0.2	0.2	0.0	-	1.4	62.5	13.0	5.6	-	-	4.1
STUC	0.1	1.9	0.1	1.2	1.5	0.5	0.1	1.5	31.2	42.8	8.3	3.1	6.9	1.0
STSR	-	2.2	-	1.8	0.3	0.1	0.0	0.0	13.9	25.4	23.2	0.5	32.4	0.1
STMC	-	1.5	-	2.5	2.0	0.7	0.1	0.3	22.9	36.9	5.7	2.2	23.9	1.2
STUW	-	99.6	-	-	-	-	-	0.4	-	-	-	-	-	-
STPS	0.0	1.3	0.9	5.6	6.0	2.8	1.1	2.6	57.1	11.2	3.8	4.2	0.9	2.6
STLC	-	1.9	0.2	4.5	3.2	1.2	0.3	1.2	58.9	15.7	4.1	5.2	0.7	2.9

Gaseous ammonia emissions contribute to downstream nonpoint source pollution which can have a large impact on water quality, where emissions from the agricultural sector (fertilizers, manure/waste streams) are the dominant source at the continental scale (Paulot et al. 2014), while emissions from gasoline (three way catalytic reduction) and diesel (selective catalytic reduction) vehicle fleets are a substantial ammonia source in urbanized and highly populated areas of the United States (Sun et al. 2017, Fenn et al. 2018).Wildfires are an important natural terrestrial source of gaseous ammonia in smoke plumes as well, which can contribute to downwind secondary particulate formation and eventual nutrient enrichment in aquatic and terrestrial ecosystems upon deposition (Prenni et al. 2014, Lindaas et al. 2021a, Lindaas et al. 2021b). As wildfires become increasingly prevalent in the western United States, gas and diesel vehicle fleets are sustained/expanded with population growth and the agricultural sector maintains food production demands, the impacts on air and water quality will continue to be affected by these air pollution sources. Agricultural related air quality has been deemed the greatest environmental risk factor associated with mortality nationally and globally (Domingo et al. 2021). However, with effective BMPs for livestock waste management, fertilizer applications and improved crop and animal production practices, $PM_{2.5}$ mortalities could be reduced by 50%

by reducing ammonia emissions and $PM_{2.5}$ formation (Domingo et al. 2021). Additionally, aerosols and particulates can undergo chemical transformations under specific conditions and can be transported from the emission source, a process that is dependent on a variety of environmental factors. For example, wildfire plumes can transport ammonia-related pollution across state boundaries and ongoing research is actively investigating plume chemical reactions that can take place depending on wildfire dynamics, which will be important to track as these events become more prominent across the western US.

Surface water pH or acidity can be influenced by both natural and anthropogenic environmental factors including precipitation containing CO_2, groundwater percolating through soils that may add additional buffering capacity to waterbodies, surface water alkalinity, biological processes (i.e., photosynthesis and respiration), and inputs of biomass that can contribute acids to watershed soils and surface waters (e.g., pine/fir needles). Localized/regional geology, soil composition, and physiography characteristics heavily dictate natural surface water alkalinity (e.g., limestone/bicarbonates/carbonates within watersheds) or the ability to regulate/neutralize acidity levels within lakes and streams, such that alkalinity is a property that indicates the potential sensitivity of surface waters to acid deposition/hydronium ion inputs (USEPA 1986). Alkalinity is typically inversely related to elevation (as observed in the Cascade Mountain Range) and largely dictated by the suite of rock types resulting from the rich geologic history (e.g., glaciation, tectonic activity, sedimentary, oceanic basalts), such that typical surface water alkalinity levels are highest at lower elevations across the eastern portion of the state and decrease with elevation in the western portion (USEPA 1986). Excessive nutrient loading from surficial runoff and other nonpoint source pollution stimulates photosynthesis during the growing season and eventual respiration/decomposition of organic matter, which can cause pH changes (increased acidity with CO_2 release during respiration) and actively recycle nutrients (such as nitrogen and phosphorus) in aquatic ecosystems. Anthropogenic activities that can influence pH include acid rain, increases in CO_2 atmospheric concentrations, industrial point source and mining discharge pollution. Atmospheric pollutants that lead to acid rain (e.g., sulfates, nitrates corresponding to SO_2 and NOx emission sources) can be introduced to waterbodies directly, episodically through melting of snowpack/extreme weather events resulting in downpours/stormwater runoff, and through flushing of soils. While pollutants that lead to acid rain have declined considerably due to federal regulations under the CAA, these sources can still be a source of acid to aquatic systems—an important determinant of the potential for ammonia toxicity.

Water temperature can be impacted by a variety of environmental factors pertinent in the Pacific Northwest corresponding to climate change associated air temperature changes, weather patterns, land-use activities, dam impoundments, snowmelt regimes/timing, flow regulation and other hydrologic processes that regulate heat flux, as well as short-term natural variability, and increasing wildfire prevalence (USEPA 2020a). Additional environmental factors and/or land-use activities that result in warmer stream/riverine temperatures include the removal of vegetative shade-cover provided by shrubs and trees, excessive irrigation water withdrawals and warm irrigation return flows, lower base-stream flows due to wetland losses and groundwater withdrawals, and widening of channels decreasing the overall channel depth (i.e., altering channel morphology) (USEPA 2003). As a result of these impacts, waterbodies with designated uses for Pacific salmonids and other cold water species, such as along the Columbia and Snake Rivers, face considerable challenges regarding the health, migration behavior and survival of these species due to suboptimal temperature conditions within critical habitat (Crozier et al. 2008a, Crozier et al. 2008b, USEPA 2020a). Just within the mainstem of the Columbia and Snake Rivers, water temperatures have increased by 1.5°C ± 0.5°C since 1960 and are predicted to continue rising in the coming decades as much as 1-5°C by the end of the century, which includes Columbia River tributaries (USEPA 2020a).

As discussed in above (section 4.3.1), pH and temperature act as critical controls on the total ammonia composition and relative toxicity provided the ratio of NH_3:NH_4^+. Climate change associated impacts related to temperature and pH in addition to increasing nonpoint source pollution continues to be a challenge to regulate and likely will become more problematic in the coming decades regarding ecosystem impacts from nutrient inputs (e.g., nitrogen and ammonia's role in nitrogen cycle) in attempts to sustain food production demands, at the cost of contributing to particulate matter formation and associated consequences for human health, degraded water quality and corresponding surface water uses.

4.4 Baseline Exposure of Listed Species to CWA Activities Intended to Control Ammonia Concentrations

Of the 90 NPDES permittees with discharge limits and/or monitoring requirements for ammonia, 2/3 are located within 100 meters of critical habitat including most salmonid ESUs, marbled murrelet, and eulachon (Table 4-7, Figures: 4-1, 4-7 - 4-13). Puget Sound and Columbia River salmonid ESUs have 5 or more regulated facilities within range of the following ESUs (COLC, CHRC, CKPS, CKLC, STPS, STUC, STMC, STLC; Table 4-7, Figures: 4-1, 4-9 - 4-13). 58 facilities (64% of total dischargers) are located within steelhead habitat (Table 4-7, Figures: 4-1, 4-10). Although the majority of permittees (48%) located in steelhead habitat reside within two ESUs (STMC and STPS), dischargers exist in every ESU (with the exception of STUW; Table 4-7; Figures 4-1, 4-10). Similarly, Chinook habitat contains a large proportion of dischargers with ammonia limits and/or monitoring (38% or 34 facilities), which span all ESUs except for CKUW (Table 4-7; Figures: 4-1, 4-11). No facilities were within 100 meters of green sturgeon habitat, however one permittee was identified just upstream and noted in Table 4-7 with an asterisk (1*) as a conservative estimate that accounts for possible downstream impacts (Figures: 4-1, 4-8).

Assessment units assigned to Category 5 (impaired) and 4a (impaired with TMDL) are only found in proximity to salmonid critical habitat (Table 4-7). Of note, Chinook, sockeye and steelhead have ESU critical habitat located near Category 5 listings (CKSS, CKSF, CKPS, SOSR, STUC, STMC, STPS), while Category 4a assignments are located close/within coho, chum, Chinook and steelhead (COLC, CHCR, CKSS, CKLC, STSR, STMC, STLC) ESU habitat (Table 4-7; Figures: 4-2, 4-9 - 4-13). One impaired waterbody was identified within 100 meters of sockeye (SOSR) and steelhead (STMC) habitat and we note three (3*) upstream impaired waterbodies as potentially having a downstream impact on these ESUs as indicated by the asterisk (Table 4-7; Figures: 4-2, 4-9 – 4-10).

In many cases, in Washington, NPDES permitting and impaired waters assessment activities utilize the chronic ammonia criteria rather than the acute criteria.

Table 4-7. Summary of permitted dischargers monitoring for ammonia, with ammonia limits, and impaired water bodies listed under category 5 (impaired) and 4a (impaired waterbodies with TMDLs) relative to species habitat and based on the proposed 2018 Washington State Water Quality Assessment.

Summary of facilities monitoring for NH_3 with established limits and impaired waterbodies (Category 4a and 5) relative to species habitat			
Species	**Facilities with NH_3 limits & in-situ monitoring**	**4a**	**5**
MAMU	1	-	-
ORSF	-	-	-
BUTR	-	-	-
GRST	1*	-	-
EULA	1	-	-
ORCA	-	-	-
COLC	8	1	-
CHCR	8	1	-
CHHC	1	-	-
CKUC	3	-	-
CKSS	2	1	-
CKSF	1	-	1
CKUW	-	-	-
CKPS	20	-	3
CKLC	8	1	-
SOSR	2	-	1, 3*
SOOL	-	-	-
STUC	5	-	4
STSR	2	1	1
STMC	22	1	1, 3*
STUW	-	-	-
STPS	22	-	5
STLC	7	1	-

* Indicates category 5 listings or permittees that are located just upstream of species habitat, therefore accounted for with respect to a given evolution significant unit (ESU).

5. Effects Assessment

5.1 Effects Assessment Methodologies

Biological effects to aquatic listed species were assessed through a hybrid tiered/weight of evidence approach. Please see Figure 5-1 below for a conceptual diagram outlining the decision-making process used to inform final effects determinations.

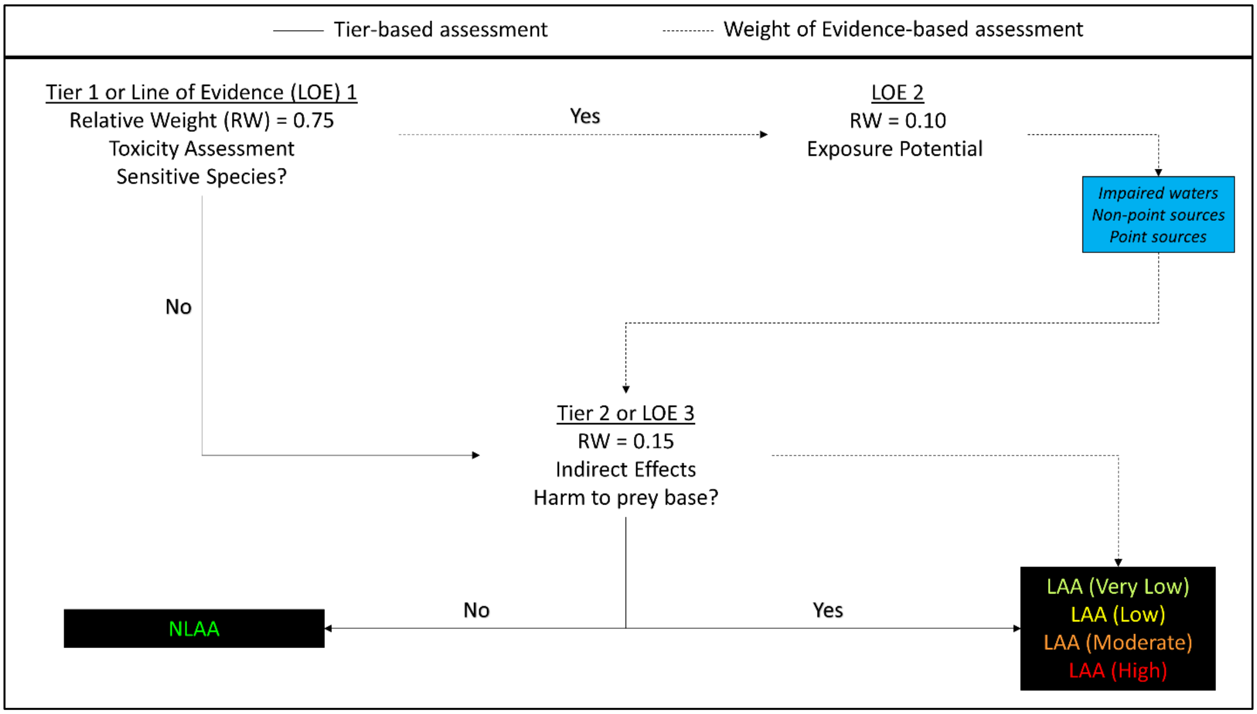

Figure 5-1. Effects assessment methodology to inform final effect determination based on direct and indirect biological effects.

5.1.1 Hybrid Tiering/Weight of Evidence Decision Making Process for the Analysis of Effects of the Action on ESA Listed Species

EPA considered multiple factors regarding the protectiveness of Washington's freshwater acute ammonia criteria for specific species in order to determine if a species is or is not likely to be adversely affected (LAA or NLAA, respectively) by its 2008 approval action. The analysis was focused on the effect of the action on individual members of a species. The multiple factors were considered in a systematic way, which either involved a series of binomial decision points (tiering) or a range of options (weight of evidence, WOE), depending upon the species sensitivity to ammonia, in order to develop a ranked based conclusion process for NLAA or LAA determinations in section 6 (Figure 5-1). The effects determinations are classified as LAA or NLAA but are given a qualifier in this BE of Very Low, Low, Medium, or High depending on the level of information or evidence indicative of an adverse effect on an individual member of a species.

The qualifying label is only intended to provide the Services with a rapid way to gauge the relative extent of the information supportive of a LAA determination. The qualifying terms are not intended to and do not meet a regulatory threshold. The idea for this type of qualification can also be found in the Biological Evaluations produced by the EPA's Office of Pesticide Programs for diazinon, chlorpyrifos, and malathion; however, those three BEs contained a more quantitative rendition of a WOE approach than this BE. The driving impetus in using a weight of evidence approach was to transparently rank the relative strength evidence for conclusions EPA makes in section 6. As a note of context, ecological risk assessment, and perhaps the field of statistics, is moving away from making decisions on thresholds to making decisions based on gradients or probabilities and a weighing of multiple lines of evidence.[17]

As the information in this BE involves a level of uncertainty in exposure and effects of chemical substances on T/E species, it is important to recognize this uncertainty and when possible and appropriate, formally and transparently integrate it into the assessment. Although the approach herein does not produce a formal quantitative assessment of risk, it does provide a means to relatively rank the level of evidence for LAA/NLAA for each species assessed. However, the hybrid of tiering and weight of evidence approach was used to demonstrate EPA's higher level of confidence in Tier 1 for the overall effect determinations made in section 6 of this BE and as a way to defer to the protection of the species in the face of uncertainty.

The following tiers or lines of evidence provide information on both the toxic effect on organisms as well as the potential for exposure to ammonia in Washington surface freshwaters.

- *Tier 1* or *Line of Evidence (LOE) 1*: Protectiveness of ammonia acute criteria magnitude[18] for each listed entity (species or critical habitat) in a range of Washington water chemistry conditions
- *Line of Evidence 2*: Potential for exposure to ammonia from point and non-point sources
- *Tier 2* or *Line of Evidence 3*: Effects of the ammonia criteria on species food resources

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[17] Suter, G. Weight of Evidence in Ecological Assessment. US EPA Office of Research and Development, Washington, DC, EPA100R16001, 2016; INSIGHT: Weight-of-Evidence Best Way to Manage Chemical Risks (https://news.bloombergenvironment.com/environment-and-energy/insight-weight-of-evidence-best-way-to-manage-chemical-risks); Nature Comment. Scientists rise up against statistical significance. 2019. https://www.nature.com/articles/d41586-019-00857-9

[18] The ammonia criteria employ three elements to protect aquatic life: criteria magnitude, duration, and frequency of exceedance. However, as existing ammonia toxicity data were not reviewed to evaluate whether exposure duration alters toxicity and because limited data exist to assess the effect of frequency of exposure on toxicity, EPA focused its assessment on criteria magnitude (a conservative choice). The goal of the assessment of criteria magnitude was to evaluate the protectiveness of the authorized criteria concentrations for listed species rather than to evaluate the effect of measured ammonia concentrations in ambient waters on listed species, as the latter is part of the Environmental Baseline (section 4).

5.1.1.1 Tiered/Weight of Evidence Hybrid for the Analysis of Effects

As shown in Figure 5-1, to make an effects determination for each species, EPA proceeded in two distinct paths depending on the sensitivity[19] of a species. For insensitive species, EPA evaluated the effects of the action on prey species, after which, EPA completed its analysis and effects determination. This tiered approach was thus only used for insensitive species. For sensitive species, EPA proceeded to evaluate the WOE for LAA using multiple LOEs. Therefore, the overall process is referred to as a hybrid approach and is described in more detail below.

5.1.1.2 Tiered Effects Assessment Approach

The tiered effects assessment begins with analyzing a given species sensitivity to ammonia and whether the criteria are protective for direct toxicity to a species. Tier 1: If a species acute toxicity value (LC_5) was > all corresponding criteria values (CMC) across water chemistries relevant to that species, the criteria were determined to be protective for direct toxicity, so EPA proceeded to Tier 2, effects assessment in which toxicity to prey species was considered. If, however, a species toxicity value was < a corresponding criteria value at any water chemistry, the EPA proceeded to Line of Evidence 2 as described below.

5.1.1.3 Weight of Evidence Approach

As noted above, when the Tier 1 analysis indicated an insensitive species, EPA proceeded to Tier 2 and did not evaluate exposure in LOE 2. If, however, a sensitive species was found in Tier 1/LOE 1, EPA proceeded to LOEs 2 and 3 and assembled the information as described below.

Each LOE was weighted, on a relative scale from 0.0 - 1.0, according to the level of uncertainty associated with each LOE, as well as each LOE's relative relevance of the effects of the action. Low uncertainty coupled with a high relevance to the effects of the action tended to increase the weight of a LOE. Each LOE and the relative weighting factors are described in Table 5-1. The way in which EPA translated each LOE into an overall WOE assessment is described below.

On a species by species basis, each LOE received a **score** of 0, 1, 2, 3, or 4 depending on the level of information indicating that an adverse effect is likely to occur to an individual member of an ESA listed species. The score for each LOE was then multiplied by the **relative weight** to obtain a **LOE Score**. LOE Scores were added and divided by 4 (i.e., the maximum possible score indicating high certainty of adverse effects) and multiplied by 100% to obtain a **WOE Score** that provides a relative measure of evidence for a LAA determination. The resultant species-specific WOE Score was used to provide information on the level of evidence for the potential that an adverse effect would occur as a result of the proposed action.

- *Tier 1/LOE 1*: Direct toxicity assessment
    - The percent of samples in which the criteria value (CMC) was > species toxicity value (LC_5)

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[19] A "sensitive" species is one in which the relevant toxicity value (Lethal Concentration at the x^{th} centile (LCx) is less than the respective criterion value (CMC) respectively) in one or more (i.e., >0%) Washington surface water samples included in this analysis. Insensitive species have toxicity values that are never less than the criteria value.

        - This information was used to estimate percent of a population that might be affected (e.g., if 99% of samples have a CMC > LC5, then 4.95% (i.e., 0.99 x 0.05 = 0.0495) of the individuals exposed *at the CMC concentration* may be affected at the 5% effect level (by comparison, if the CMC > LC5 for 1% of samples, this would suggest a 0.05% chance that mortality would occur in a species). The scoring system is considered conservative because it relies on the assumption that water concentrations in the environment are at the criterion concentration long enough (e.g., 96 hours) to exert toxicity. Note that Washington's WQS indicates that TAN can only exceed, on average, the CMC for one-hour once in three years. As exposure at the criteria concentration is not expected to occur in all circumstances, EPA proceeded to an exposure analysis for LOEs 2 and indirect effect analysis in LOE 3.
    - A LOE Score of 0-4 was determined as follows:
        - 0: 0% LC5 < CMC
        - 1: 1-25% LC5 < CMC
        - 2: 26-50% LC5 < CMC
        - 3: 51-75% LC5 < CMC
        - 4: 76-100% LC5 < CMC
- *LOE 2*: Exposure potential of an ESA listed species to ammonia in locations where the ammonia criteria may be used (e.g., for effluent permits, assessments, total maximum daily load limitations, or site cleanup activities). This analysis was not conducted in this BE because Tier 1/LOE 1 indicated no sensitive species. Therefore, calculation information is not provided here.
- *Tier2/LOE 3*: Scoring system to evaluate the effects of the proposed action on a species food resources (formerly referred to as the indirect effects of the action). This analysis was based on the fraction of species within a community of surrogate prey items that may experience acute toxicity given the proposed action. That is, the percent of genus mean acute values (GMAVs) that were lower than the CMC were determined (See section 5.1.4 for more information). The following logic was then used to determine the level of evidence for an effect of the proposed action on food resources.
    - A LOE Score of 0-4 was determined as follows:
        - 0: When 0-20% GMAVs < CMC
        - 1: When 21-40% GMAVs < CMC
        - 2: When 41-60% GMAVs < CMC
        - 3: When 61-80% GMAVs < CMC
        - 4: When 81-100% GMAVs < CMC

Table 5-1. Relative weights assigned to each line of evidence (LOE) in the weight of evidence calculations

LOE	Relative Weight	Explanation for Relative Weight
1	0.75	High level of certainty compared to the other LOEs;[1] direct effect on species; action agency has the authority to determine the nature of its approval action
2	0.10	Low level of certainty in the analyses given that the data analyzed were collected as part of the Environmental Baseline; action agency has oversight authority, but this authority is outside the scope of this action, to mitigate

LOE	Relative Weight	Explanation for Relative Weight
		effects through implementation programs (NPDES permits, assessments, TMDLs)
3	0.15	Medium level of certainty; indirect rather than a direct effect on species; action agency has the authority to determine the nature of its approval action

[1] Level of certainty based on relevance and reliability of data used for the assessment

Using the available information EPA calculated WOE Scores for each species as follows (also see Attachment 1):

$$\frac{\sum_{i=1}^{n} LOE\ Score\ \times Relative\ Weight}{4} \text{ X } 100 = \text{WOE Score}$$

Where, n = 3

The WOE Score can be interpreted as the level of evidence indicating the potential for an adverse effect to an individual member of a species to occur under the assumptions used in the analysis (Table 5-2). The calculations of LOE and WOE Scores can be found in Attachment 1. The final effects determinations based on these analyses can be found in section 6.

Table 5-2. Interpretation of weight of evidence (WOE) Scores into the level of evidence for a likely to adversely affect (LAA) interpretation

WOE Score	Level of Evidence for LAA	Interpretation
0	Insignificant	NLAA
1-25	Very Low	LAA
26-50	Low	LAA
51-75	Moderate	LAA
76-100	High	LAA

5.1.2 LOE 1/Tier 1: Direct Acute Effects Assessment Methodology

The effects of acute ammonia exposures, consistent with Washington's freshwater acute ammonia criterion magnitude element (but not frequency and duration criteria elements), were assessed by identifying or estimating acute toxicity values (i.e., LC_{50}) for Washington aquatic ESA listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Acute toxicity values used to develop the acute effects assessments were obtained from three different sources. First, values were taken from Appendix A of the 304(a) aquatic life criteria documents for ammonia (USEPA 2013) that were specifically used to derive EPA's 2013 acute criterion (i.e., bold values in Appendix A of USEPA 2013). These data were from studies identified in EPA's ECOTOX database, as well as additional studies from peer-reviewed and grey literature and have been subjected to extensive data quality review see Stephen et al. (1985) for data quality objectives). However, because the current assessment was conducted in 2021, EPA updated its ammonia toxicity dataset by querying EPA's ECOTOX database for published and catalogued data as well as the Web of Science to acquire newly published data regarding freshwater ammonia toxicity published between 2012 to 2021. These sources were similarly verified for quality as described above. Acute ammonia values are presented as normalized to a pH of 7 (all freshwater animals) and 20°C (freshwater invertebrates only), consistent with criteria derivation (USEPA 2013).

Ideally, species-specific toxicity data for ESA listed species of concern would be available to support an acute effects assessment; however, data limitations often required use of surrogate toxicity data. EPA considered acute toxicity data at the closest taxonomic level possible to calculate geometric mean acute toxicity values (i.e., LC_{50}) for each species assessed. Considering surrogate toxicity data at the most phylogenetically related taxonomic level possible accounted for genetically derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean acute toxicity values at the genus, family, and order-level were calculated as the geometric mean of lower taxonomic-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon. Species-specific and surrogate acute toxicity data represent sensitivity expressed as a concentration that will acutely affect half of the exposed species population. Acute toxicity data (expressed as LC_{50}) were therefore adjusted to an acute minimum effect threshold concentration (i.e., LC_5) that represents a concentration expected to affect 5% of the test population of a ESA listed species under continuous exposure conditions in a 96-hour toxicity test for fish, or a 48-hour toxicity test for specific invertebrate species (e.g., *Ceriodaphnia dubia*). Representing acute minimum effect thresholds as an LC_5 value is conservative because high-quality toxicity tests are considered acceptable even when up to 10% mortality is observed in the control treatment (organisms not exposed to the pollutant). Additionally, quantifying responses at the statistical tail (e.g., $< LC_{10}$) of a non-linear distribution is highly uncertain (e.g., large 95% confidence intervals) and becomes statistically infeasible at the LC_0.

Raw empirical acute toxicity data may be used to calculate LC_5 values directly from the concentration-response (C-R) curves of the ESA listed species-specific toxicity tests, when available. However, not all acute tests provide C-R data. Therefore, species-specific, or surrogate LC_{50} values (which represent ESA listed species 50% effect level), were transformed to an acute minimum effect threshold concentration through an acute taxonomic adjustment factor (TAF) or an acute mean adjustment factor (MAF). An acute TAF was calculated by averaging (geometric mean) the ratios of LC_{50}:LC_5 from chemical-specific acute toxicity tests conducted using species from the closest possible phylogenetic category (i.e., same species, genus, family, or order) to the ESA listed species that is being assessed (genus, family, and order-level acute TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean acute TAFs to ensure adequate representation of all lower-level taxa for a particular taxon).

When data availability did not allow for the development of an acute TAF within the same order as the species being assessed, EPA considered applying an acute invertebrate or vertebrate TAF (depending on whether the ESA listed species assessed was an invertebrate or vertebrate). The acute invertebrate TAF and the acute vertebrate TAF were calculated as the geometric mean of genus-level LC_{50}:LC_5 ratios of invertebrates and vertebrates, respectively. An acute MAF was used to adjust species effect concentrations (i.e., LC_{50}) to low effect threshold concentrations (i.e., LC_5) when: (1) an acute TAF was not available within the same order as the ESA listed species being assessed and (2) when the acute invertebrate TAF and the acute vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The acute MAF was calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios available. Acute invertebrate and vertebrate TAFs and the acute MAF were calculated as the geometric mean of their respective genus-level LC_{50}:LC_5 ratios to limit the influence of LC_{50}:LC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

After calculating appropriate adjustment factors, ESA listed species-specific or surrogate LC_{50} values were then divided by the appropriate adjustment factor (i.e., acute TAF or acute MAF depending on data availability) to derive an acute minimum effect threshold concentration. Dividing LC_{50} values by an adjustment factor to identify a minimum-level effect concentration is an approach that is fundamentally similar to acute criteria derivation,[20] but is more specific to the chemical and species assessed. Acute minimum effect threshold concentrations were then compared to corresponding criterion magnitudes (i.e., criterion maximum concentration [CMC]) to assess potential direct adverse effects of ammonia exposures at the acute criterion concentration over conservative exposure durations).

Washington's acute freshwater ammonia criterion magnitude is modified when the designated use of the waterbody is classified for salmonids. Currently, all fresh surface waters of Washington state are designated as "salmonids present". As described in USEPA (2013), vertebrate sensitivity and thus acute criteria decrease as pH increases to reflect the increase in unionized ammonia as pH rises (Figure 5-2). Because both vertebrate sensitivity (e.g., LC_5) and the CMC change with ambient pH, the acute effects assessment described in this document was developed using both toxicity data normalized to reference conditions (pH = 7) as well as conditions specific to Washington surface waters. Note that both the CMC and the LC_5 do not change with changing temperature as described in USEPA 2013 and in Appendix D of that document.

[20]The Final Acute Value (FAV; fifth centile of genus mean acute values) is divided by 2.0 to derive the **Criterion** Maximum Concentration (CMC). The FAV was divided by 2.0 to ensure the CMC is representative of a concentration that will not severely adversely affect too many organisms. To support the development of the 1985 Guidelines, a Federal Register notice published in 1978 (Vol 43, pp. 21506-21518; USEPA 1978) outlined the derivation of a generic LC_{50} to LC_{low} (i.e., 0-10% effect) adjustment factor of 0.44 (or divide by 2.27). The adjustment factor of 2.27 was derived as the "*geometric mean of the quotients of the highest concentration that killed 0-10% of the organisms divided by the LC_{50} in 219 acute toxicity tests*." The geometric mean adjustment factor (2.27) outlined in the 1978 Federal Register notice was subsequently rounded to 2.0 in the 1985 Guidelines (Stephan et al. 1985).

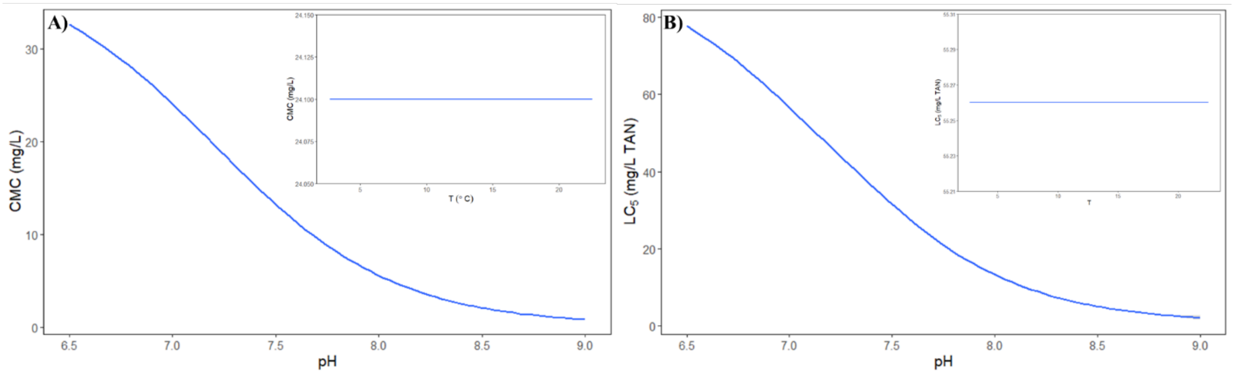

Figure 5-2. Change in (A) acute criteria magnitude (CMC) and (B) vertebrate sensitivity (LC5) as pH changes. The insets demonstrate the lack of change in CMC and LC_5 (Chinook salmon only) as temperature increases at a pH of 7 (representative of other pH values).

Assessing the acute criterion magnitude alone did not consider the duration and frequency components of the criterion and represents a conservative exposure scenario that assumes a pollutant concentration in all Washington freshwaters will be at the acute criterion magnitude indefinitely. If a ESA listed species acute minimum effect threshold concentration was less than the corresponding acute criterion magnitude, then an exposure assessment was conducted as part of LOE 2 before determining whether the action would be NLAA or LAA a species. Conversely, when the CMC < LC_5, LOE 2 was not evaluated.

5.1.3 LOE 2: Exposure Assessment Methodologies

The following information is provided only for completeness. However, note that because no species were sensitive as determined in LOE 1/Tier 1, an evaluation under LOE 2 was not conducted.

As described in the WOE methodology overview (section 5.1.1), LOE 2 deals with the exposure potential of a species to ammonia in locations where the ammonia criteria may be used. Potential uses include derivation of protective effluent permit limits, assessments for impaired waters, total maximum daily load determinations, and site cleanup activities. The results of LOE 2 may help the Services determine the likelihood that ESA listed species would experience exposures to ammonia in circumstances that would be subject to the approval of the Washington ammonia criteria. In section 4 (Environmental Baseline) of this BE, EPA reviewed the factors associated with potential ammonia releases into the environment and how these activities overlapped with locations where T/E species may occur. Through this process, EPA gained a better understanding of the exposure potential to ammonia. The intent of an analyses presented in LOE 2 would be to better contextualize the analysis conducted for LOE 1. In other words, EPA would address the question: in what locations in Washington might species exposures to ammonia more likely reach criteria concentration levels? As this analysis is subject to a fair amount of uncertainty, EPA would not solely rely on conclusions made in LOE 2 for its final effects determinations. Given the uncertainty of the available information and how it applies to EPA's action and given that the action does not include implementation activities, EPA assigned a relative WOE of 0.10 to LOE 2 in its final weighing of the evidence in section 6.

5.1.4 LOE 3/Tier 2: Methodologies to Evaluate the Effects to ESA Listed Species' Prey

Following the assessment of direct acute effects, EPA considered and assessed potential effects of the water quality standard approval actions on prey of aquatic organisms and aquatic-dependent animals (note, aquatic-dependent species were not evaluated for potential direct effects given no meaningful exposure).[21] EPA did not include a full evaluation of effects of the water quality standard approval action on food resources for listed aquatic/semi-aquatic plant species because such effects are not likely to adversely affect plants given their life histories and biology (i.e., assimilate nutrients from sediments and energy through photosynthesis).

The assessment of the proposed action on prey of ESA listed aquatic and aquatic-dependent animals was used evaluate whether criteria concentrations may elicit toxicity to a "meaningful portion" of the ESA listed species diet (Suter II et al. 2000). All potential prey or surrogate prey species of an ESA listed species (i.e. the community of prey species of an ESA listed species) were assessed. This section of the BE evaluates whether the water quality criterion may adversely affect the assemblage of potential prey items through the "lens" of predator-prey relationships between ESA listed species and their prey. The ESA listed species evaluated in this BE are secondary or tertiary consumers in aquatic food webs, whose health may be adversely affected by reductions in the number of prey species available to them. This situation is most likely to occur when prey species are as a group more sensitive to a chemical than are the listed fish species.

Effects to a "meaningful portion" of prey has not been previously defined for the purposes of biological evaluations by EPA. Therefore, a definition of "meaningful portion" is described herein. Informed by recent biodiversity research on how changes in species richness may affect ecological communities, it is apparent that a decline of more than 20% in species richness has detrimental effects to communities (Vaughn 2010, Hooper et al. 2012). Therefore, a "meaningful portion" for purposes of the analysis in this BE is defined as an adverse effect to ≥20% of prey species potentially consumed by a ESA listed species. A 20% change in species richness is consistent with other lines of evidence in water quality criteria derivation and ecological risk assessment, where a 20% change in a parameter is used as a threshold for adverse effects (Suter II et al. 2000).

Reduction in the availability of prey for an ESA listed species may result in reduced growth, fitness and density (number of individuals in a population per unit of area, such as within the action area), especially when and where an ESA listed species is food-limited (Grunblatt et al. 2019). Although other community attributes can also indirectly affect an ESA listed species, species richness is by far the most studied community structure metric to evaluate the potential for larger scale effects (Daam et al. 2019, van der Plas 2019). For example, reduction in prey species richness has been directly linked to changes in fish biomass, production and yield (Smokorowski and Kelso 2002, Brooks et al. 2016), allowing prey species richness to serve as a surrogate measure for predator species abundance. However, alternative considerations from the 20% threshold were made for ESA listed species that primarily rely on a specific species such as

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[21] In the past, the evaluation of the effects of the action on an ESA listed species' prey has been referred to as analysis of the "indirect effects" of the action. Although this BE uses both terms, it is immaterial because the analysis and conclusions are the same either way.

Orcinus orca's reliance on Chinook salmon. The information above forms a basis for the logic used in assigning scores for LOE 3. See section 5.1.1.3.

5.1.5 Listed Species: Final Species Effects Determinations

Final effect determinations were based on the WOE as described in section 5.1.1, which considers direct toxicity and toxicity to prey as a result of EPA's approval of the freshwater acute ammonia criteria in Washington. For aquatic listed species, EPA considered direct acute effects as well as effects to prey in order to make a final effects determination. For aquatic-dependent listed species, such as birds and mammals, EPA concludes there will be no direct effects of ammonia in freshwater (as a result of no meaningful direct exposure) and made a final effects determination based on effects to prey only.

5.1.6 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

Following the final effects determinations to ESA listed species, EPA made critical habitat effects assessment for designated critical habitat pertaining to aquatic and aquatic-dependent species in the action area. EPA considered Physical and Biological Features (PBFs) essential to critical habitat and potential effects to listed species prey items to determine if the proposed action is *Likely to Adversely Affect* or *Not Likely to Adversely Affect* critical habitat.

5.2 Species Effects Assessments

Species effects assessments (LOE 1 and LOE 3) are presented below. All acute toxicity data used for these assessments can be found in the tables shown below for each species and in Attachment 2 and USEPA 2013.

5.2.1 Green Sturgeon (*Acipenser medirostris*)

5.2.1.1 Identifying Green Sturgeon Acute Ammonia Data

High-quality species-level or genus-level acute toxicity data were not available for green sturgeon; however, genus-level acute toxicity data from (Fontenot et al. 1998) were available to represent the sensitivity of this sturgeon species to acute ammonia exposures. The *Acipenser* genus mean acute value (GMAV), 156.70 TAN (TAN-mg/L) normalized to a pH of 7, is based on a single species mean acute value (SMAV) (see Table 5-3).

Table 5-3. Data used to calculate the Acipenser GMAV representative of green sturgeon sensitivity to ammonia. Data expressed as TAN (TAN-mg/L)

Family	Species	SMAV[a]	Reference	GMAV[a]
Acipenseridae	Green sturgeon, *Acipenser medirostris*	N/A	N/A	156.70
Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	156.70	Fontenot et al. 1998	

[a] Normalized to a pH 7 (USEPA 2013).
N/A: not available.

5.2.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity C-R data were not available for the green sturgeon and surrogate species through taxonomic order (i.e., Acipenseriformes). Therefore, a vertebrate acute adjustment factor was selected using the following analytic approach. All acceptable acute ammonia toxicity tests with available raw data were fit to C-R models using the "analysis of dose-response curves" (drc) package within the R statistical software program (versions that were current in June of 2019). Please see Appendix C for curve fitting and curve assessment methodologies. Briefly, C-R data were fit using a suite of models and the most appropriate model fit for each set of C-R data was selected based on statistical metrics. Selected models were then evaluated to determine whether they were (1) acceptable for quantitative use, (2) qualitative use, or (3) unacceptable for use. Appendix B contains raw C-R data, corresponding point estimates (i.e., LC_x), model fits, and use classification for all acute C-R models that were considered quantitatively acceptable or qualitatively acceptable.

Because no acceptable C-R data were available for Acipensiformes species, a vertebrate TAF of 1.491 was used. The vertebrate TAF is a geometric mean of all acceptable vertebrate C-R data. A MAF was not used in this case because the invertebrate TAF was significantly ($P < 0.05$) different than the vertebrate TAF. In addition to Appendix B, please see the attached supplemental information: *NH3_Supplemental_Information_A*, for acute C-R curves and model diagnostics.

5.2.1.3 Calculating Green Sturgeon Acute Ammonia Minimum Effect Threshold

Dividing the estimated Green Sturgeon GMAV (156.7 TAN-mg/L) by the acute vertebrate TAF (1.491) results in an acute minimum effect threshold concentration (LC_5) of 105.10 TAN-mg/L (normalized to a pH 7 and 20°C).

5.2.1.4 Evaluating Green Sturgeon Sensitivity to Ammonia in Washington Surface Freshwaters

Because no paired freshwater ammonia and pH data were available for green sturgeon, the assessment for green sturgeon is based only on normalized conditions (pH 7).

5.2.1.5 Green Sturgeon: Acute Ammonia Effects Determination

The acute ammonia CMC calculated at pH 7 and (24.10 TAN-mg/L) is 4.4 times lower than the acute ammonia minimum effect threshold (LC_5) of 105.10 TAN-mg/L calculated for the green sturgeon. As a result, the acute ammonia water quality standard is NLAA the green sturgeon through direct acute effects.

5.2.1.6 Assessment of Effects on Green Sturgeon Prey

The green sturgeon is a bottom-dwelling species, mostly seen from inshore waters to 200 feet, primarily in the seawater and mixing zones of bays and estuaries. In estuaries, they concentrate in deep areas with soft sediments and move into intertidal areas to feed at high tides. Adults may travel tens of miles upstream to spawn in rivers and require good water quality and specific temperatures to spawn and hatch their eggs. Both juveniles and adults move extensively along the Pacific coast to take advantage of scattered food resources. Juveniles remain in freshwater for one to four years before heading to more estuarine waters, where they remain for up to four to six years, during which they can migrate considerable distances along the coast as they grow larger.

Green sturgeon is an opportunistic predator and will consume a variety of available prey types. These fish feed by using an elongated mouth appendage that sucks food and sediment from the sediment surface. Burrowing shrimp species (e.g., Neotrypaea spp.) are an important dietary component for subadult and adult green sturgeon, but green sturgeon also eat fish (e.g., lingcod), crab (e.g., Cancer spp.), amphipods (e.g., Anisogammarus spp.), clams (e.g., Cryptomya californica), and polychaetes (Dumbauld et al. 2008) (NMFS 2018). Similarly, juvenile green sturgeon feed upon shrimp, amphipods, isopods, clams, annelid worms, and an assortment of crabs and fish in the San Francisco Bay Delta Estuary(Ganssle 1966, Radtke 1966, NMFS 2018). Diet for the larval stage of green sturgeon is largely unknown; however, it is assumed to be similar to that of the white sturgeon which would include insect larvae, oligochaetes, and decapods (NOAA Fisheries 2009). After spawning, adults likely feed on benthic prey species such as lamprey ammocoetes and crayfish. Adult green sturgeon and near adult green sturgeon are found in bays and coastal regions, with diets consisting of shrimp, clams, crabs, and benthic fish. Recent evaluations of subadult green sturgeon captured in the California halibut trawl fishery suggest their diet consists of right-eyed flatfish, shrimp, bivalves, and crabs (NMFS 2018).

As a result of the potential for prey to be affected by ammonia in freshwater and thus prey availability for green sturgeon, EPA evaluated the toxicity of ammonia to surrogate prey items. Table 5-4 is the USEPA 2013 ammonia acute criterion dataset to show species or surrogates that represent possible green sturgeon prey items. The most sensitive potential prey item (i.e., lowest GMAV) is noted by green shading. All other potential prey items would therefore be less sensitive than the green-shaded cells and have higher GMAVs. GMAVs are based on LC_{50} values are at reference water conditions (pH 7).

Table 5-4. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded row indicates the most sensitive potential prey item for green sturgeon

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Although juvenile green sturgeon feed upon a large assortment of invertebrates, it is possible that *Venustaconcha ellipsiformis* provides an indication of toxicity that may be experienced by a prey item consumed by green sturgeon. The Venustraconcha GMAV at pH 7 and 20°C is 23.12 TAN-mg/L. The CMC at those same normalized conditions is 24.1 TAN-mg/L. However, given that only two of 69 (2.9%) GMAVs are lower than the CMC, and that juvenile green sturgeon feed on shrimp, amphipods and other invertebrates that are less sensitive than mollusks, juvenile green sturgeon prey availability is not expected to be significantly affected by ammonia at CMC concentrations. As a result, EPA approval of Washington's freshwater acute ammonia standard is NLAA green sturgeon through a reduction in prey availability.

5.2.2 Oregon Spotted Frog (*Rana pretiosa*)

5.2.2.1 Identifying Oregon Spotted Frog Acute Ammonia Data

High-quality species-level acute toxicity data were not available for the Oregon spotted frog. Available genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 96.38 TAN-mg/L (normalized to pH 7) representative of the Oregon spotted frog (Table 5-5). The *Rana* GMAV is based on the Leopard frog SMAV (96.38 TAN-mg/L) (Diamond et al. 1993), normalized to a pH 7.

Table 5-5. Data used to calculate the *Rana* GMAV representative of Oregon spotted frog to ammonia

Family	Species	SMAV (TAN-mg/L)[a]	Reference	GMAV (TAN-mg/L)[a]
Ranidae	Leopard frog, *Rana pipiens*	96.38	Diamond et al. 1993	96.38
Ranidae	Oregon spotted frog, *Rana pretiosa*	N/A	N/A	

[a] Normalized to a pH 7 (USEPA 2013).
N/A: not available.

5.2.2.2 Deriving LC_{50} to LC5 Acute Adjustment Factor

Raw empirical toxicity data were not available for the Oregon spotted frog at the species-, genus-, or family-level, and therefore, no raw empirical toxicity data were available to support the derivation of an LC_{50}:LC_5 acute adjustment factor for the family *Ranidae*. As a result, an order level LC_{50}:LC_5 acute adjustment factor of 2.188 was calculated from quantitatively-acceptable C-R model data from the order Anura (Table 5-6).

Table 5-6. Acute LC_{50}:LC_5 ratio from the analysis of a high-quality acute ammonia toxicity test with a frog species for the derivation of an acute ammonia order TAF representative of the Oregon spotted frog. (Note: the acute order TAF is the geometric mean of all available genus-level LC_{50}:LC_5 ratios).

Order	Family	Species	LC_{50} (TAN-mg/L)	LC_{05} (TAN-mg/L)	LC_{50}:LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})	Family-level TAF (LC_{50}:LC_{05})	Order-level TAF (LC50:LC_{05})
Anura	Ranidae	Pacific tree frog, *Pseudacris regilla*	64.43	29.45	2.188	Am-Acute 80	(Schuytema and Nebeker 1999)	2.188	2.188	2.188	2.188

5.2.2.3 Calculating Oregon Spotted Frog Acute Ammonia Minimum Threshold

Dividing the *Rana* GMAV (96.38 TAN-mg/L) by the acute Anura order-level TAF (2.188) resulted in an acute minimum effect threshold concentration of 44.05 TAN-mg/L (normalized to pH 7) that is representative of the Oregon spotted frog.

5.2.2.4 Evaluating Oregon Spotted Frog Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, Oregon spotted frog acute LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding Oregon spotted frog acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in Oregon spotted frog range (n = 47).

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figure 5-3)[22]. Data points above the linear line indicated scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, "nLC_5", the range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and spotted frog acute effect threshold data (i.e., LC_5) are reported in Table 5-7.

[22] R statistical computing software was used to create Figure 5-3 and all subsequent figures plotting CMC versus LC_5 data in this BE. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, 2020.

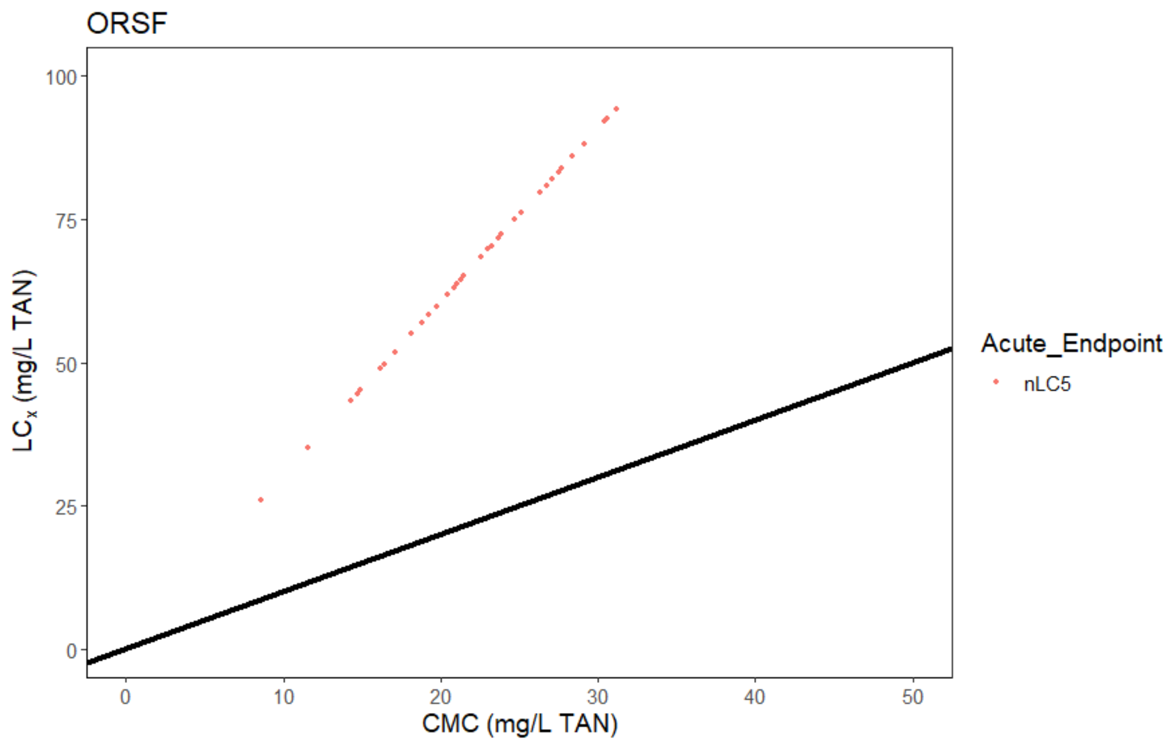

Figure 5-3. **Paired Oregon spotted frog acute effect concentrations (LC_5) and acute criterion values (CMC) in Oregon spotted frog range (n=47). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_5 and CMC values.**

Table 5-7. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the Oregon spotted frog acute effect concentration (LC_5). Comparisons are based only on paired pH and temperature collected from within Oregon spotted frog range.

Species Name	Paired pH and Temperature Samples (n)	CMC > LC5	
		n	%
Oregon spotted frog	47	0	0

5.2.2.5 Oregon Spotted Frog: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.10 TAN-mg/L) is 1.8 times lower than the acute ammonia minimum effect threshold (LC_5) of 44.05 TAN-mg/L total ammonia calculated for the Oregon spotted frog. Furthermore, there were no occurrences in Oregon spotted frog range in which the CMC was greater than the LC_5. That is, the Oregon spotted frog acute minimum effect threshold concentration, based on continuous laboratory exposures is greater than the corresponding criterion magnitude. As a result, approval of the acute ammonia WQS is NLAA the Oregon spotted frog.

5.2.2.6 Assessment of Effects on Oregon Spotted Frog Prey

The Oregon spotted frog is an aquatic native frog in the Pacific Northwest. It is found in or near perennial water bodies, including zones of shallow water and abundant emergent or floating aquatic plants (Hallock 2013). The Oregon spotted frog prefer fairly large, warm marshes that can support a population to persist despite high predation rates and sporadic reproductive failures.

Oregon spotted frog tadpoles are predominately herbivorous, feeding on algae, decaying vegetation, and detritus. After they undergo metamorphosis, they become opportunistic predators (Licht 1974), as reported in Hallock (2013). Insects [terrestrial] were observed as being the primary food source with the types of insects growing larger as the frog did the same. It has also been observed that the adults will occasionally prey upon other frog species such as newly metamorphosized Northern Red-Legged frogs and juvenile Western Toads (Hallock 2013).

Table 5-8. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded row indicates the most sensitive potential prey item for Oregon spotted frog.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus (LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

As discussed in EPA's 2013 ammonia criteria document, freshwater and estuarine/marine algae and plants were not more sensitive than vertebrates and invertebrate animal taxa to ammonia exposures, so plant criteria were not developed. USEPA (2013) states, "*The data available on the toxicity of ammonia to freshwater plants indicate that plants are approximately two orders of magnitude less sensitive than the aquatic animals tested*." Oregon spotted frog does not feed on freshwater mussels, which are considered the most sensitive genera to chronic ammonia exposures (USEPA 2013). Furthermore, the Oregon spotted frog is largely a generalist feeder, often times relying on terrestrial-based food resources that will experience no meaningful exposure to ammonia. The most sensitive potential prey item GMAV was 71.56 TAN-mg/L as shown above, which is higher than the CMC of 24.1 TAN-mg/L at pH 7. Consequently, EPA approval of the Oregon freshwater acute ammonia criteria is NLAA the Oregon spotted frog through degradations to its food resources.

5.2.3 Eulachon (*Thaleichthys pacificus*)

5.2.3.1 Identifying Eulachon Acute Ammonia Data

High-quality species-level acute toxicity data were not available for the eulachon. Therefore, per EPA practices in a recent BE (USEPA 2020b) and NOAA's agreement[23] (NMFS 2012b) with the practice, Salmonidae toxicity data provided surrogacy for the eulachon's sensitivity to ammonia toxicity. The Salmonidae FMAV is the geometric mean of Salmo, Salvelinus, and Oncorhynchus species GMAVs (from a total of 170 total toxicity tests) as shown in Table 5-9. The eulachon toxicity value is the FMAV of 128.84 TAN-mg/L (normalized to pH 7).

[23] Email communication with NOAA Fisheries Biologist, Jeff Vanderpham, on April 30, 2021 relayed information from NOAA's eulachon expert, Rick Gustafson, that "biologically it makes sense to use salmonids as a proxy for osmerids, on both a taxonomic level and behaviorally. Eulachon are anadromous like most Pacific salmonids, where most of the toxicological work has been done. Thus, he felt that salmonids are the best surrogate for eulachon."

Table 5-9. Data used to calculate the Salmonidae FMAV representative of eulachon's sensitivity to ammonia

Family	Genus	Species	SMAV (TAN-mg/L)[a]	Reference	GMAV (TAN-mg/L)[a]	FMAV (TAN-mg/L)[a]
Osmeridae	Thaleichthys	Eulachon, *Thaleichthys pacificus*	N/A	N/A	N/A	128.84
Salmonidae	Salvelinus	Lake trout, *Salvelinus namaycush*	159.30	(Soderberg and Meade 1993)	157.80	
		Brook trout, *Salvelinus fontinalis*	156.30	(Thurston and Meyn 1984)		
	Salmo	Brown trout, *Salmo trutta*	102.00		136.70	
		Atlantic salmon, *Salmo salar*	183.30	(Knoph 1992, Soderberg and Meade 1993)		
	Oncorhynchus	Chinook salmon, *Oncorhynchus tshawytscha*	82.39	(Thurston and Meyn 1984, Servizi and Gordon 1990)	99.15	
		Rainbow trout, *Oncorhynchus mykiss*	82.88	(DeGraeve et al. 1980) (Wicks and Randall 2002) (Thurston et al. 1983) (West 1985) (Arthur et al. 1987) (Reinbold and Pescitelli 1982c) (Thurston et al. 1981a) (Broderius and Smith Jr 1979) (Thurston et al. 1981c) (Calamari et al. 1977) (Wicks et al. 2002)		
		Coho salmon, *Oncorhynchus kisutch*	87.05	(Wilson 1974) (Robinson-Wilson and Seim 1975) (Buckley 1978)		
		Pink salmon, *Oncorhynchus gorbuscha*	180.70	(Rice and Bailey 1980)		
		Cutthroat trout, *Oncorhynchus clarkii*	78.92	(Thurston et al. 1978)		
		Golden trout, *Oncorhynchus aguabonita*	112.10	(Thurston and Russo 1981)		

5.2.3.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC_{50}:LC_5 ratio for the eulachon. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for eulachon.

5.2.3.3 Calculating Eulachon Acute Ammonia Minimum Threshold

Dividing the eulachon toxicity value (Salmonidae FMAV of 128.84 TAN-mg/L) by the corresponding acute species-level TAF (1.492) resulted in an acute minimum effect threshold concentration of 86.41 TAN-mg/L (normalized to pH 7).

5.2.3.4 Evaluating Eulachon Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, eulachon LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding eulachon acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in eulachon range (n = 441).

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figure 5-4). Data points above the linear line indicated scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, "nLC_5", the eulachon range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and eulachon acute effect threshold data (i.e., LC_5) are reported in Table 5-10.

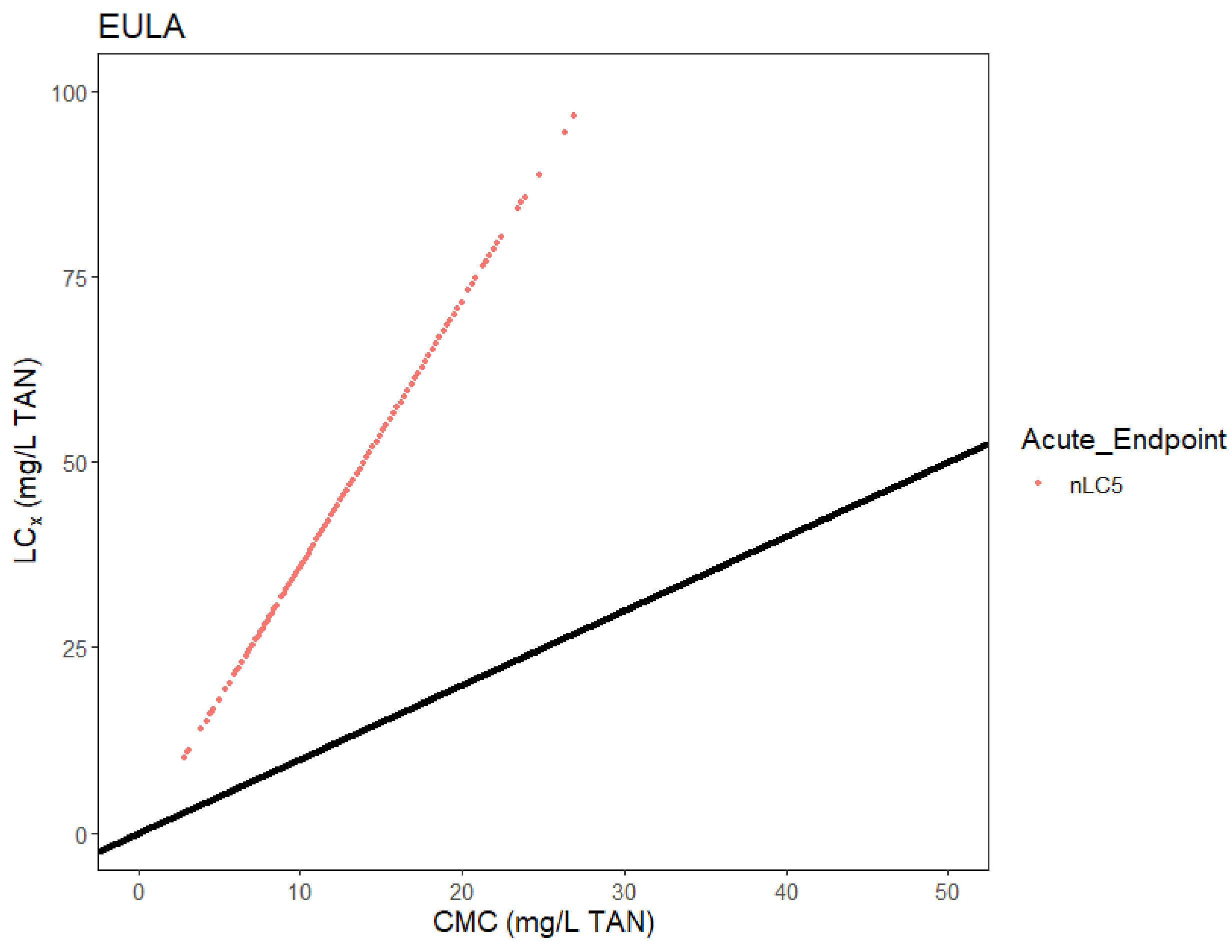

Figure 5-4. Paired eulachon acute effect concentrations (LC_5) and acute criterion values (CMC) in eulachon range (n=441). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

Table 5-10. number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the eulachon acute effect concentration (LC_5). Comparisons are based only on paired pH and temperature collected from within eulachon range.

Species Name	Paired pH and Temperature Samples (n)	CMC > LC_5	
		n	%
Eulachon	441	0	0

5.2.3.5 Eulachon: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.1 TAN-mg/L) is 5.3 times lower than the eulachon, acute ammonia minimum effect threshold of 128.84 TAN-mg/L. Furthermore, there were no occurrences in eulachon range in which the CMC was greater than the LC_5. That is, the eulachon acute minimum effect threshold concentration, based on continuous laboratory exposures is greater than the corresponding criterion magnitude. As a result, approval of the acute ammonia WQS is NLAA the eulachon.

5.2.3.6 Assessment of Effects on Eulachon Prey

Pacific eulachon are an anadromous, short-lived, high-fecundity, high-mortality forage fish. Eulachon spawn in freshwater streams. As the spawning season approaches, eulachon gather in large schools off the mouths of their spawning streams and rivers. Also like the anadromous salmonids, the majority of adult eulachon die soon after spawning.

Eulachon dietary information is limited, particularly for juveniles. River currents purportedly carry newly hatched young to the sea where they feed mainly on copepod larvae and other plankton (Willson et al. 2006) . Adults are primarily plankton-feeders. However, the fall studies have shown that their stomachs are not very full suggesting they do not actively feed during that time. Larval stages of the Pacific eulachon eat phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, worm larvae, and eulachon larvae (WDFW and ODFW 2001), as reported in (Willson et al. 2006).

Table 5-11. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded row indicates the most sensitive potential prey item for eulachon.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

As discussed in EPA's 2013 ammonia criteria document and shown above in Table 5-11, freshwater non-mussel invertebrates are likely far less sensitive to ammonia than mussels. As the normalized CMC is 24.1 TAN-mg/L, which is lower than the lowest GMAV (142.9 TAN-mg/L for water flea/a planktonic surrogate species) in Table 5-11. Eulachon does not feed on freshwater mussels, which are considered the most sensitive genera to chronic ammonia exposures (USEPA 2013). Consequently, EPA approval of the Washington freshwater acute ammonia WQS is NLAA the eulachon through degradations to its food resources.

5.2.4 Bull Trout (*Salvelinus confluentus*)

5.2.4.1 Identifying Bull Trout Acute Ammonia Data

High-quality species-level acute toxicity data were not available for bull trout. However, genus-level (Salvelinus) acute toxicity data were available to represent the sensitivity of bull trout. The GMAV is the geometric mean of six tests, summaries of which are shown in Table 5-12 and is 157.8 TAN-mg/L (normalized to pH 7).

Table 5-12. Data used to calculate the Salvelinus GMAV representative of bull trout sensitivity to ammonia

Family	Species	SMAV (TAN-mg/L)[a]	Reference	GMAV (TAN-mg/L)[a]
Salmonidae	Bull trout, *Salvelinus confluentus*	N/A	N/A	157.80
	Brook trout, *Salvelinus fontinalis*	156.30	(Thurston and Meyn 1984)	
	Lake trout siscowet, *Salvelinus namaycush*	159.30	(Soderberg and Meade 1993)	

[a] Normalized to a pH 7 (USEPA 2013).
N/A: not available.

5.2.4.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC_{50}:LC_5 ratio for the bull trout. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for bull trout.

5.2.4.3 Calculating Bull Trout Acute Ammonia Minimum Effect Threshold

Dividing the bull trout toxicity value (Salvelinus GMAV of 157.8 TAN-mg/L) by the corresponding acute species-level TAF (1.492) resulted in an acute minimum effect threshold concentration of 105.84 TAN-mg/L (normalized to pH 7).

5.2.4.4 Evaluating Bull Trout Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, bull trout LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding bull trout acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in bull trout range (n = 149).

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figure 5-5). Data points above the linear line indicated scenarios where the CMC was less than the corresponding chronic effect threshold data (i.e., acute endpoint, "nLC_5", the bull trout range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and bull trout acute effect threshold data (i.e., LC_5) are reported in Table 5-13.

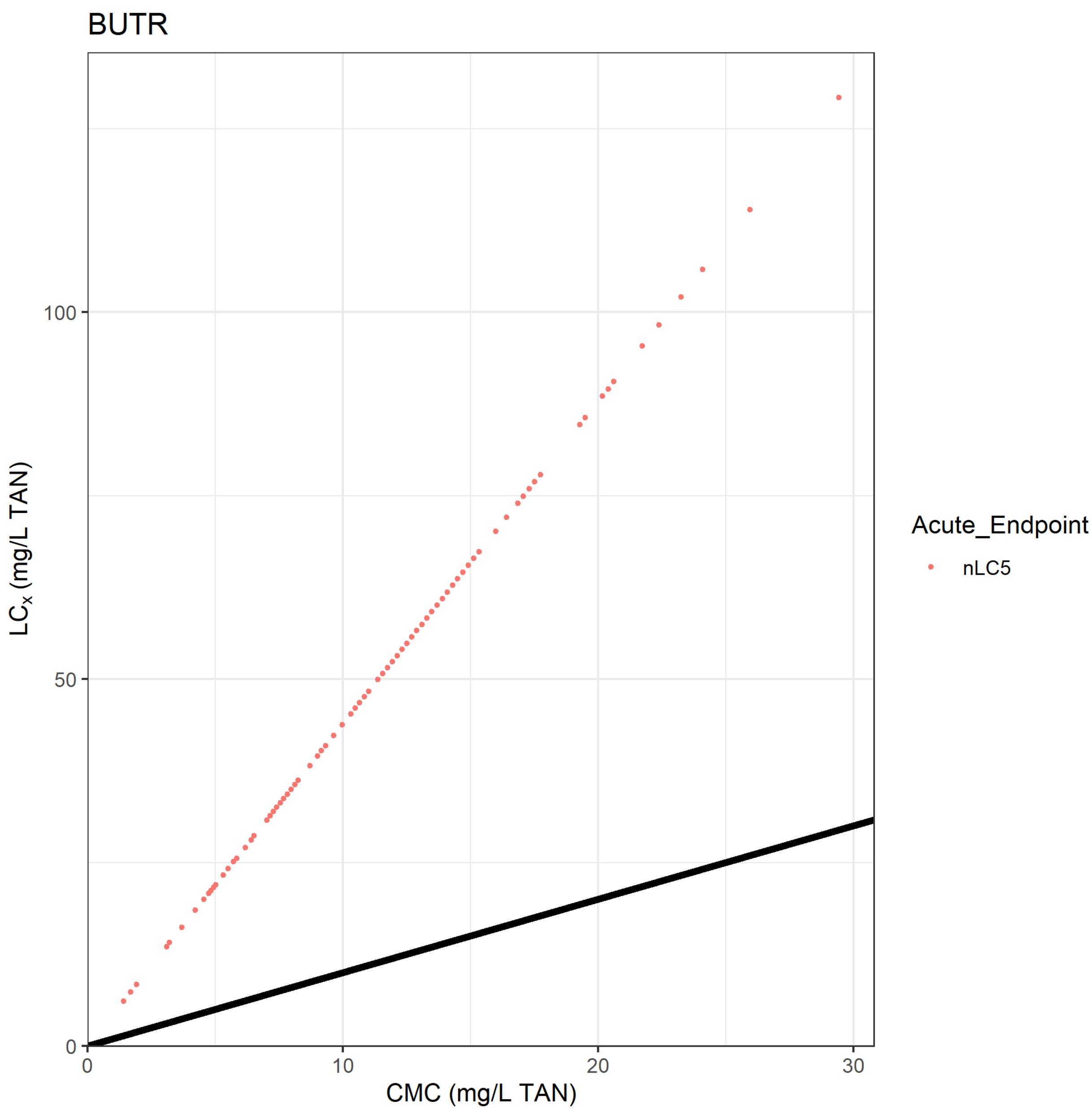

Figure 5-5. **Paired bull trout acute effect concentrations (LC_5) and acute criterion values (CMC) in bull trout range (n=149). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.**

Table 5-13. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the bull trout acute effect concentration (LC_5). Comparisons are based only on paired pH and temperature collected from within bull trout range.

Species Name	Paired pH and Temperature Samples (n)	CMC > LC_5	
		N	%
Bull trout	149	0	0

5.2.4.5 Bull Trout: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.10 TAN-mg/L), is 4.4 times lower than the bull trout acute minimum effect threshold of 105.84 TAN-mg/L. Furthermore, there were no occurrences in bull trout range in which the CMC was greater than the LC_5. That is, the bull trout acute minimum effect threshold concentration, based on continuous laboratory exposures is greater than the corresponding criterion magnitude in all evaluated conditions. As a result, approval of the acute ammonia WQS is NLAA bull trout.

5.2.4.6 Assessment of Effects on Bull Trout Prey

Bull trout are most common in high mountainous areas where snowfields and glaciers are present. They mainly occur in deep pools of large, cold rivers and lakes. Juvenile bull trout, during their first year of life, feed primarily on small aquatic invertebrates (Stewart et al. 2007). They will also intake annelids, mollusks, crustaceans such as amphipods, cladocerans, and mysids, as well as fish species that are smaller in size. Bull trout become increasingly piscivorous with increasing size, and adult bull trout diet consists primarily of other fish species. Bull trout have been known to feed on whitefish, sculpins, darters, and other species of trout and salmon. They may also partake in the occasional consumption of small birds, such as ducklings, as well as smaller mammals such as shrews and mice (Stewart et al. 2007).

Table 5-14. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded /row indicates the most sensitive potential prey item for bull trout.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Table 5-14 is the USEPA 2013 ammonia acute criterion dataset. All species in the dataset reflect species or surrogates that represent possible bull trout prey items. GMAVs (based on LC_{50} values) are at the reference water conditions (pH 7, 20°C). However, bull trout are opportunistic feeders that do not focus on mussels at early or any one life stage and become more piscivorous as they age. The CMC at reference conditions is 24.1 TAN-mg/L and the lowest two of 69 (just 2.9% of all GMAVs) GMAVs (mussel genera) are 23.12 and 23.41 TAN-mg/L. Although these GMAVs are lower than the CMC, these mussels represent just a fraction of the prey consumed by bull trout. For all the reasons presented above, the approval of Washington freshwater acute ammonia WQS is not expected to significantly reduce bull trout prey availability and is therefore NLAA bull trout through this pathway.

5.2.5 Steelhead (*Oncorhynchus mykiss*), Lower Columbia River, Middle Columbia River, Puget Sound, Snake River, and Upper Columbia River ESUs

5.2.5.1 Identifying Steelhead Acute Ammonia Data

High-quality species-level acute toxicity data were available for the steelhead. The *Oncorhychus mykiss* SMAV (82.88 TAN-mg/L) is based on 118 acute toxicity tests shown in Table 5-15.

Table 5-15. Data used to calculate the *Oncorhynchus mykiss* SMAV representative of steelhead, all ESUs

Family	Species	LC_{50} (TAN-mg/L)	Reference	SMAV (TAN-mg/L)
Salmonidae	Steelhead, *Oncorhynchus mykiss*	137.30	(Broderius and Smith Jr 1979)	82.88
		64.40	(Calamari et al. 1977)	
		108.10	(DeGraeve et al. 1980)	
		143.30	(Reinbold and Pescitelli 1982c)	
		113.40		
		116.80		
		207.90		
		136.40		
		113.70		
		69.26	(Thurston et al. 1983)	
		71.33		
		76.17		

Family	Species	LC_{50} (TAN-mg/L)	Reference	SMAV (TAN-mg/L)
		46.01		
		38.02		
		54.64		
		56.69		
		77.19		
		64.04		
		71.32		
		64.34		
		66.73		
		68.55		
		78.52		
		115.20		
		96.81		
		95.27		
		109.20		
		161.80		
		110.50		
		122.60		
		115.70		
		101.60		
		94.23		
		105.70		
		93.61		
		128.50		
		95.95		
		115.70		
		70.32		
		43.62		
		49.59		
		66.71		
		64.87		
		58.38		
		62.64		
		62.96		
		44.73		
		66.21		
		150.60		
		111.70		

Family	Species	LC_{50} (TAN-mg/L)	Reference	SMAV (TAN-mg/L)
		142.30		
		102.60		
		107.20		
		66.07		
		65.84		
		67.60		
		53.27		
		68.95		
		85.87		
		44.93		
		79.39		
		50.43		
		57.06		
		68.03		
		80.11		
		62.19		
		81.40		
		76.83		
		123.60		
		105.20		
		89.71		
		116.90		
		124.90		
		60.65		
		98.22		
		72.02		
		54.00		
		78.38		
		67.51		
		92.03		
		80.69		
		43.91		
		103.70		
		92.43		
		92.42		
		103.20		
		133.30		
		111.10		

Family	Species	LC_{50} (TAN-mg/L)	Reference	SMAV (TAN-mg/L)
		71.36		
		127.40		
		63.91	(Thurston et al. 1981a)	
		40.40		
		104.60		
		27.15		
		59.69		
		51.20		
		74.94		
		47.27		
		52.62		
		114.50	(Thurston et al. 1981b)	
		87.39		
		108.30		
		100.70		
		119.40		
		116.80	(Thurston et al. 1981c)	
		80.83		
		102.20		
		104.00		
		80.02		
		69.50		
		107.40	(West 1985) (Arthur et al. 1987)	
		96.27		
		137.80		
		54.24		
		97.57		
		212.60	(Wicks and Randall 2002)	
		201.70	(Wicks et al. 2002)	
		31.56		

[a] Normalized to a pH 7 (USEPA 2013).

5.2.5.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC50:LC5 ratio for steelhead. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for steelhead.

5.2.5.3 Calculating Steelhead Acute Ammonia Minimum Effect Threshold

Dividing the steelhead LC_{50} (82.88 TAN-mg/L; genus-level surrogate) by the vertebrate acute TAF (1.491) resulted in an acute minimum effect threshold concentration of 55.59 TAN-mg/L (normalized to pH 7).

5.2.5.4 Evaluating Steelhead Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, steelhead LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding steelhead acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in each of the five steelhead ESU ranges in Washington.

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figures 5-5 to 5-10). Data points above the linear line indicated scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, "nLC_5", the steelhead ESU range specific normalized LC_5) and data points below the 1:1 line indicated scenarios where the CMC would be greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and steelhead acute effect threshold data (i.e., LC_5) are reported in Table 5-14.

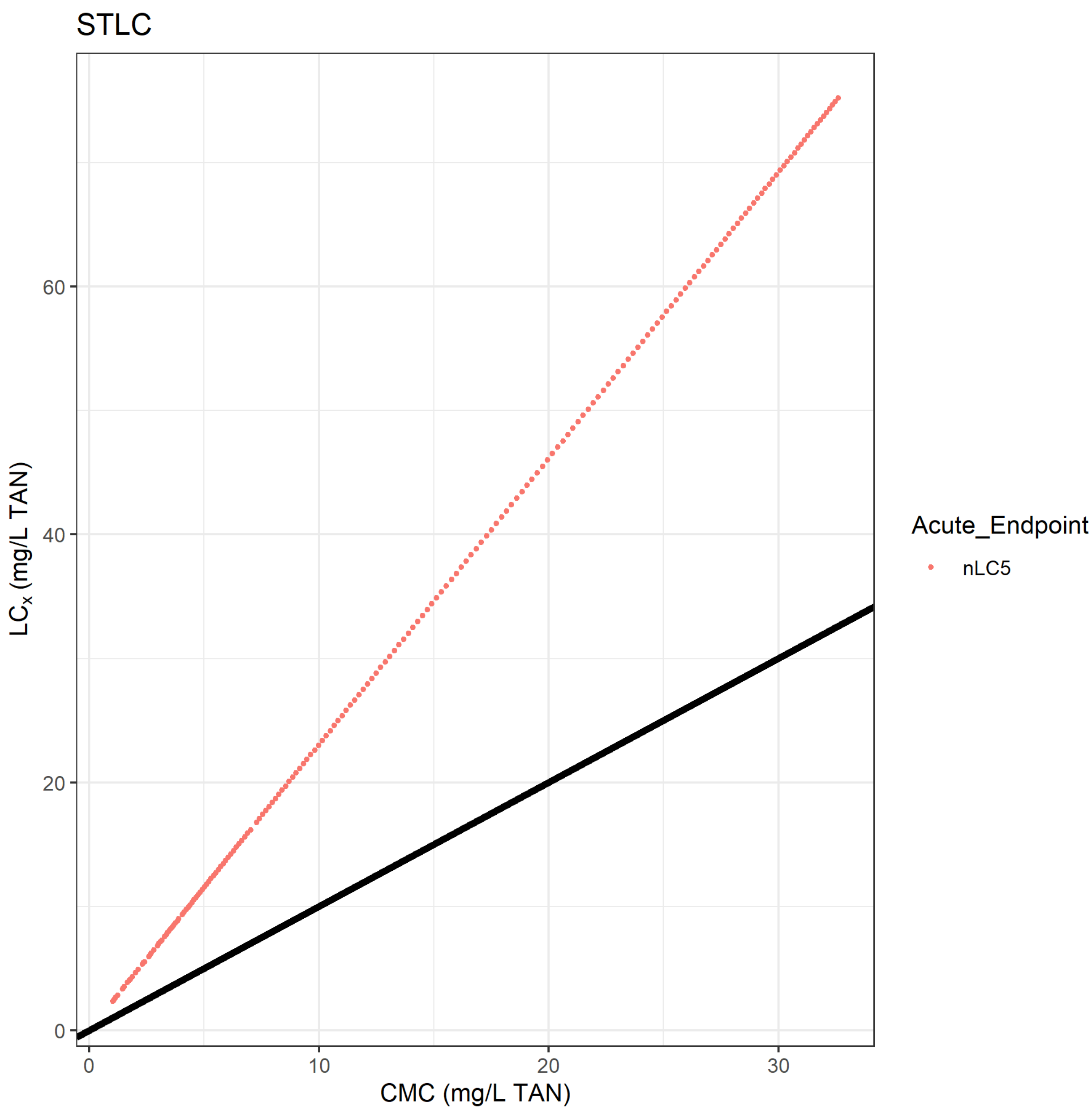

Figure 5-6. Paired steelhead Lower Columbia ESU effect concentrations (LC_5) and acute criterion values (CMC) in steelhead range (n=2662). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

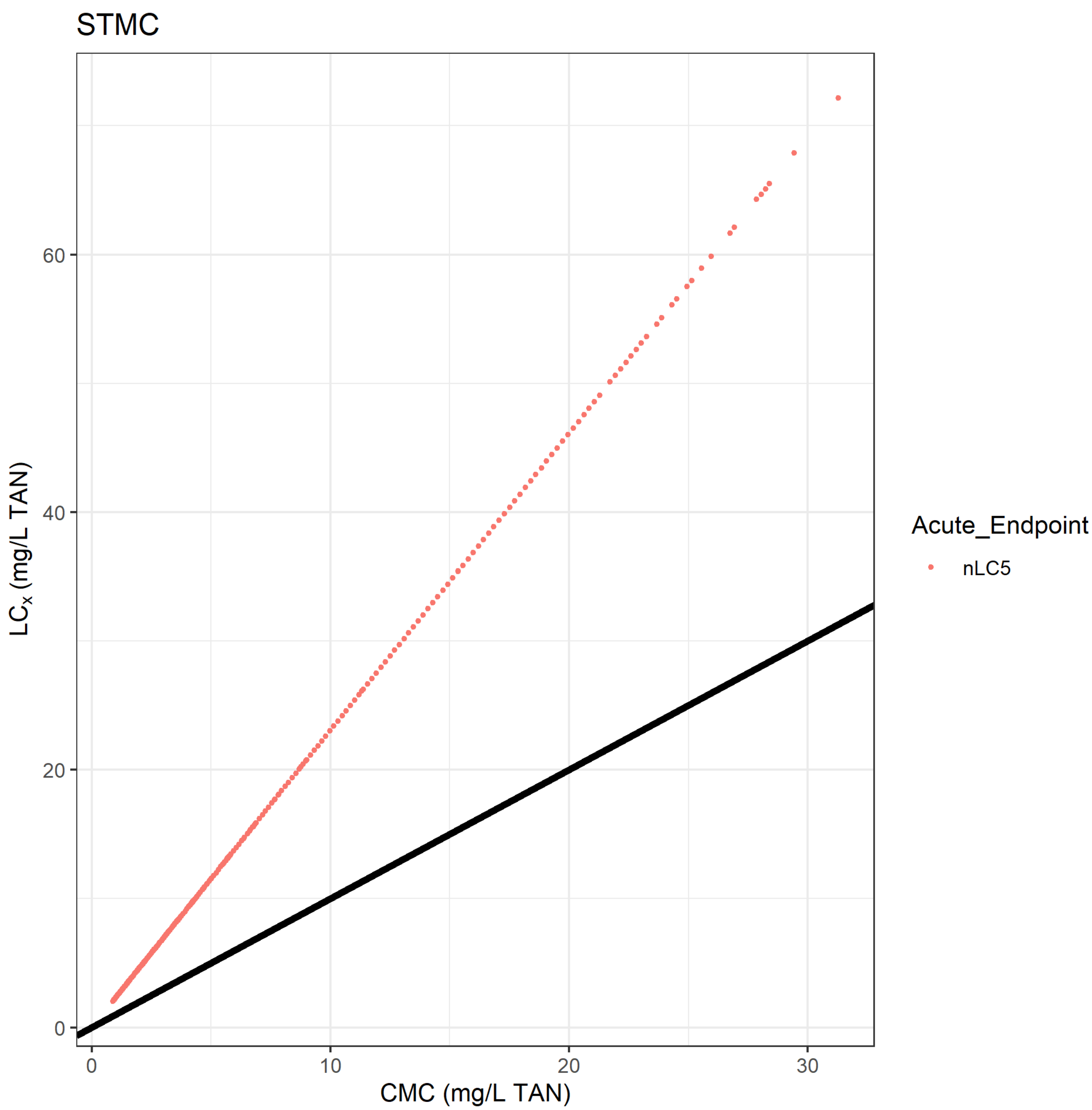

Figure 5-7. Paired steelhead Middle Columbia ESU effect concentrations (LC_5) and acute criterion values (CMC) in steelhead range (n=3506). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

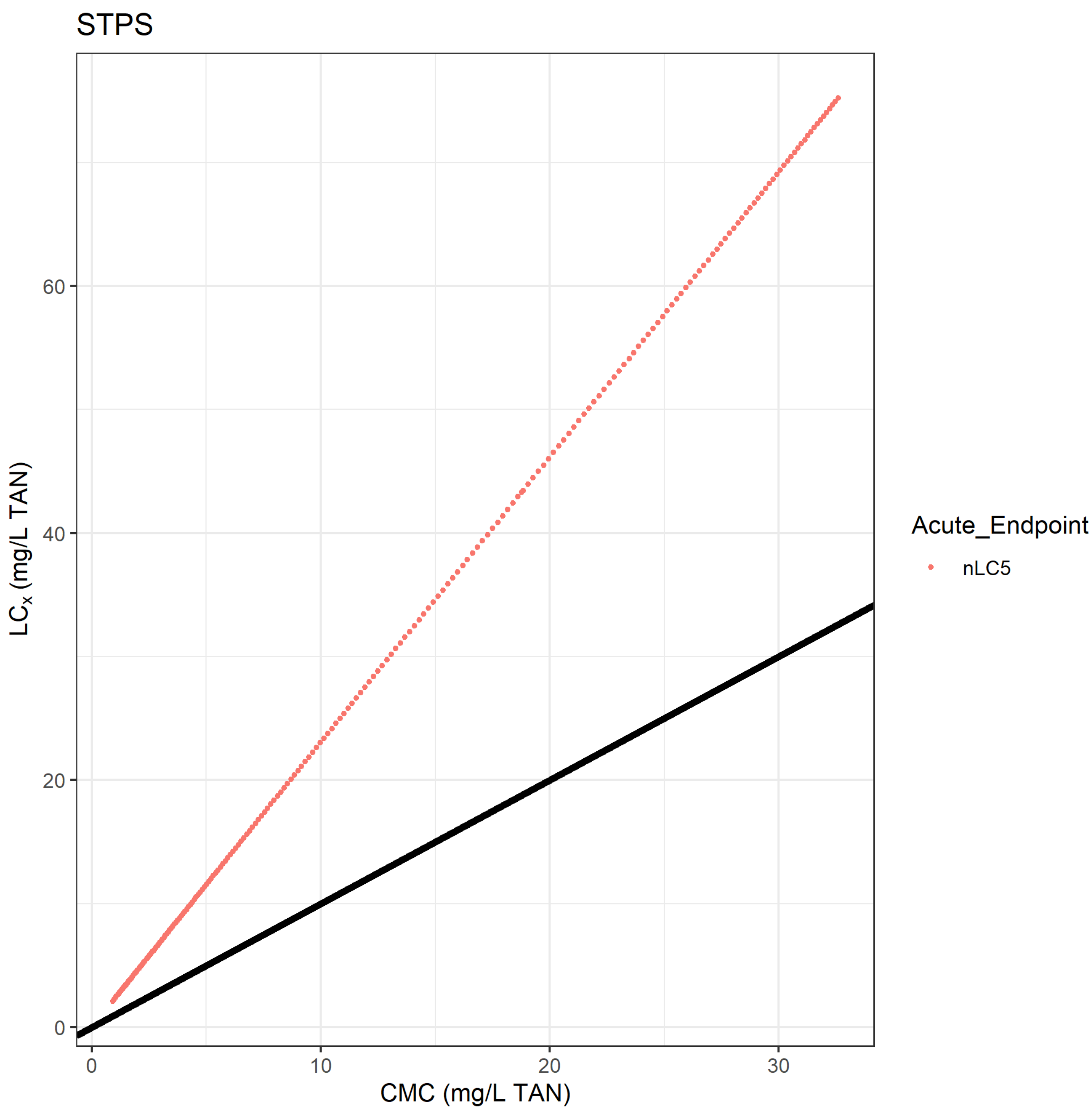

Figure 5-8. Paired steelhead Puget Sound ESU effect concentrations (LC_5) and acute criterion values (CMC) in steelhead range (n=18,480). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

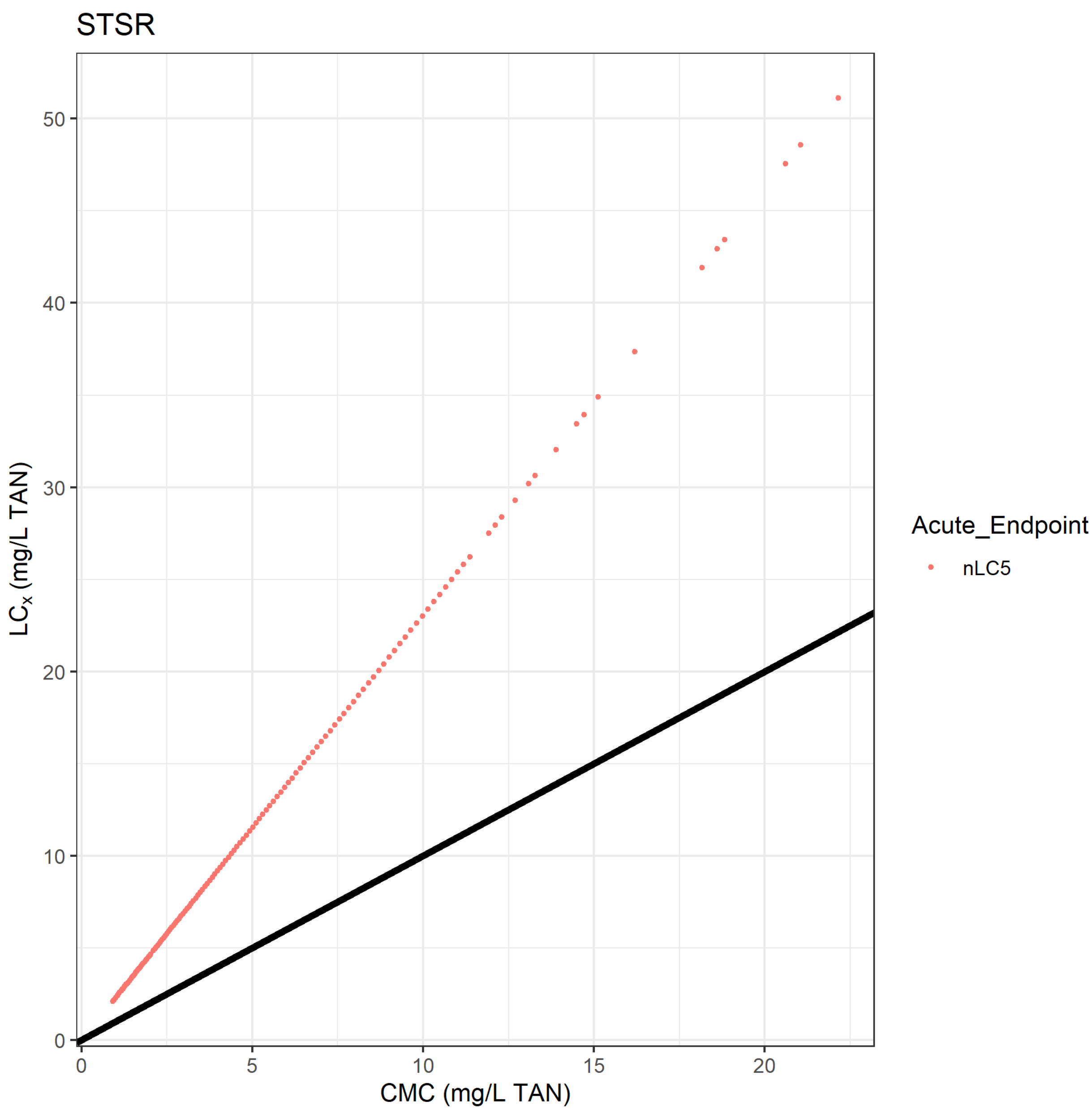

Figure 5-9. Paired steelhead Snake River ESU effect concentrations (LC_5) and acute criterion values (CMC) in steelhead range (n=1005). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

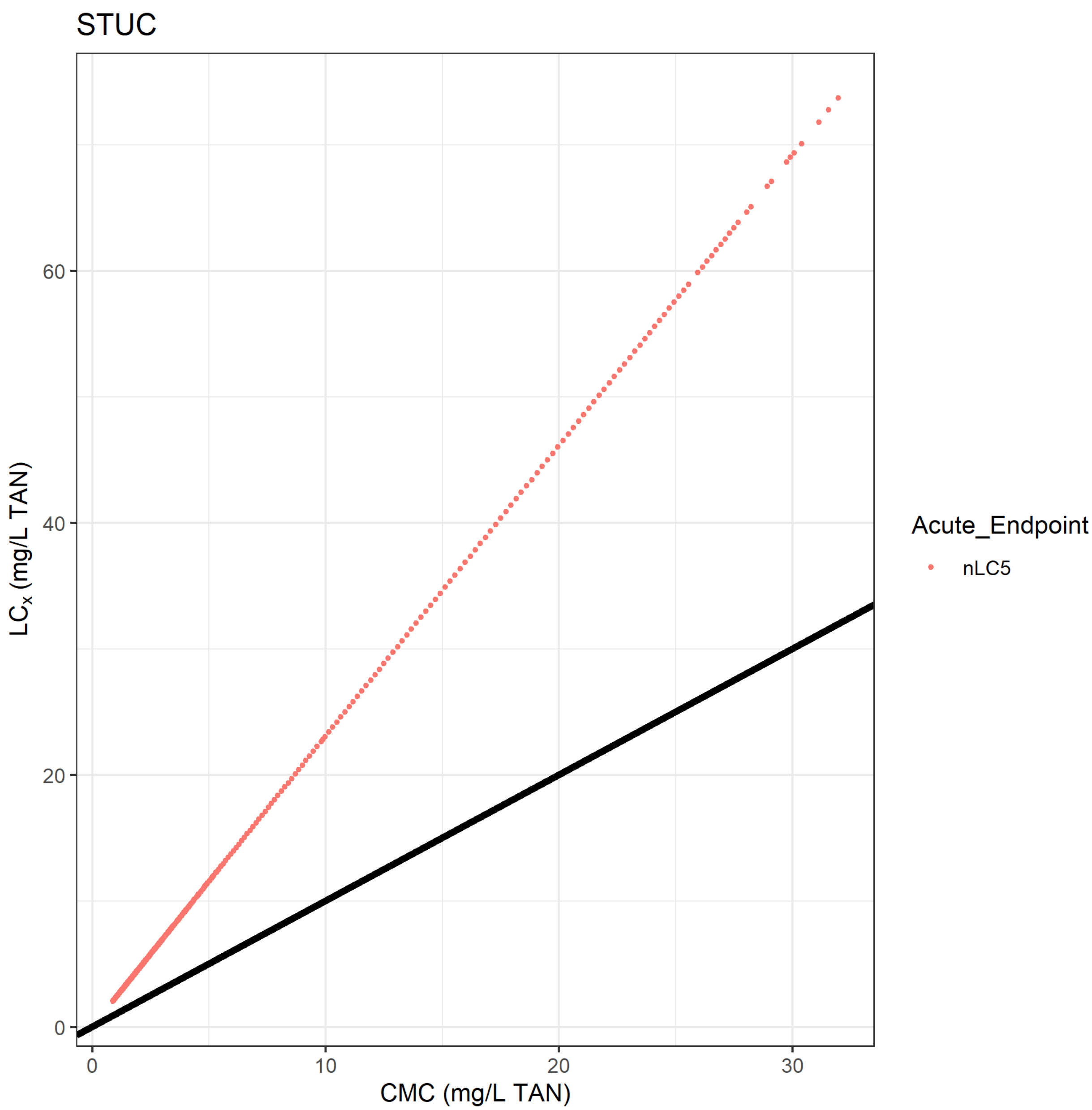

Figure 5-10. Paired steelhead Upper Columbia ESU effect concentrations (LC_5) and acute criterion values (CMC) in steelhead range (n=3987). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

Table 5-16. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the steelhead acute effect concentrations (LC_5). Comparisons are based only on paired pH and temperature collected from within steelhead ESU ranges.

Species Name	ESU	Paired pH and Temperature Samples (n)	CMC > LC_5	
			n	%
Steelhead	Lower Columbia	2662	0	0
	Middle Columbia	3506	0	0
	Puget Sound	18480	0	0
	Snake River	1005	0	0
	Upper Columbia	3987	0	0

5.2.5.5 Steelhead: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.10 TAN-mg/L) is 2.31 times lower than the steelhead acute minimum effect threshold of 55.59 TAN-mg/L, suggesting the steelhead is tolerant to ammonia at concentrations specified by the ammonia CMC under continuous exposure conditions. Further, there were no occurrences in which the steelhead LC_5 was less than the CMC in Washington waters. As a result, approval of the acute ammonia WQS is Not Likely to Adversely Affect (NLAA) all steelhead ESUs through direct acute effects.

5.2.5.6 Assessment of Effects on Steelhead Prey

Steelhead are anadromous fish species but can also live in freshwater rivers and streams, lakes, estuaries, and marine environments, depending on life history stage. As juveniles, steelhead feed broadly on benthic invertebrates, including insects, crustaceans, and mollusks as primary food sources, with dietary composition expanding with age to include small fish and thus becoming top predators. They may also eat snails, plankton, and leeches as adult fish (Mueller and Staley 2000).

Table 5-17. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded row indicates the most sensitive potential prey item for steelhead.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Table 5-17 is the USEPA 2013 ammonia acute criterion dataset. All species in the dataset reflect species or surrogates that represent possible steelhead prey items. GMAVs (based on LC_{50} values) are at the reference water conditions (pH 7, 20°C). Steelhead are opportunistic feeders that do not focus on mussels at an early or any one life stage. The CMC at reference conditions is 24.1 TAN-mg/L and the lowest two of 69 (just 2.9% of all GMAVs) GMAVs (mussel genera) are 23.12 and 23.41 TAN-mg/L. However, these mussels represent just a fraction of the prey consumed by steelhead. Furthermore, insects, a major food item for steelhead, are significantly less sensitive to ammonia than mollusks (e.g., lowest GMAV for damselfly, 164.0 TAN-mg/L). For all the reasons presented above, the approval of Washington freshwater acute ammonia WQS is not expected to significantly reduce steelhead prey availability and is therefore NLAA steelhead through this pathway.

5.2.6 Chum Salmon (*Oncorhynchus keta*)

5.2.6.1 Identifying Chum Acute Ammonia Data

High-quality acute toxicity data were not available for chum salmon. Therefore, genus-level acute toxicity data were used to derive the *Oncorhynchus* GMAV, representative of chum salmon sensitivity to acute ammonia exposures. The *Oncorhynchus* GMAV (99.15 TAN-mg/L, normalized to pH 7) was based on 141 tests generating 141 LC_{50} values and is considered representative of the chum salmon (Table 5-18).

Table 5-18. Data used to calculate the *Oncorhynchus* GMAV representative of chum salmon

Family	Species	LC_{50} (TAN-mg/L)[a]	Reference	SMAV (TAN-mg/L)[a]	GMAV (TAN-mg/L)[a]
Salmonidae	Golden trout, *Oncorhynchus mykiss*	112.10	(Thurston and Russo 1981)	112.10	99.15
	Cutthroat trout, *Oncorhynchus clarkii*	132.30	(Thurston et al. 1978)	78.92	
		112.20			
		108.70			
		93.49			
		43.24	(Thurston et al. 1981a)		
		72.73			
		48.24			
		65.73			
	Pink salmon, *Oncorhynchus gorbuscha*	198.30	(Rice and Bailey 1980)	180.70	
		164.60			
	Coho salmon, *Oncorhychus kisutch*	102.50	(Wilson 1974) (Robinson-Wilson and Seim 1975)	87.05	
		94.44			
		82.02			
		84.43			
		91.90			
		95.73			
		92.84			
		60.20	(Buckley 1978)		
	Rainbow trout, *Oncorhynchus my kiss*	137.30	(Broderius and Smith Jr 1979)	82.88	
		64.40	(Calamari et al. 1977)		
		108.10	(DeGraeve et al. 1980)		
		143.30	(Reinbold and Pescitelli 1982c)		
		113.40			
		116.80			
		207.90			
		136.40			
		113.70			
		69.26	(Thurston et al. 1983)		
		71.33			
		76.17			
		46.01			
		38.02			
		54.64			
		56.69			

Family	Species	LC_{50} (TAN-mg/L)[a]	Reference	SMAV (TAN-mg/L)[a]	GMAV (TAN-mg/L)[a]
		77.19			
		64.04			
		71.32			
		64.34			
		66.73			
		68.55			
		78.52			
		115.20			
		96.81			
		95.27			
		109.20			
		161.80			
		110.50			
		122.60			
		115.70			
		101.60			
		94.23			
		105.70			
		93.61			
		128.50			
		95.95			
		115.70			
		70.32			
		43.62			
		49.59			
		66.71			
		64.87			
		58.38			
		62.64			
		62.96			
		44.73			
		66.21			
		150.60			
		111.70			
		142.30			
		102.60			
		107.20			
		66.07			

Family	Species	LC_{50} (TAN-mg/L)[a]	Reference	SMAV (TAN-mg/L)[a]	GMAV (TAN-mg/L)[a]
		65.84			
		67.60			
		53.27			
		68.95			
		85.87			
		44.93			
		79.39			
		50.43			
		57.06			
		68.03			
		80.11			
		62.19			
		81.40			
		76.83			
		123.60			
		105.20			
		89.71			
		116.90			
		124.90			
		60.65			
		98.22			
		72.02			
		54.00			
		78.38			
		67.51			
		92.03			
		80.69			
		43.91			
		103.70			
		92.43			
		92.42			
		103.20			
		133.30			
		111.10			
		71.36			
		127.40			
		63.91			
		40.40	(Thurston et al. 1981a)		

Family	Species	LC_{50} (TAN-mg/L)[a]	Reference	SMAV (TAN-mg/L)[a]	GMAV (TAN-mg/L)[a]
		104.60			
		27.15			
		59.69			
		51.20			
		74.94			
		47.27			
		52.62			
		114.50	(Thurston et al. 1981b)		
		87.39			
		108.30			
		100.70			
		119.40			
		116.80	(Thurston et al. 1981c)		
		80.83			
		102.20			
		104.00			
		80.02			
		69.50			
		107.40	(West 1985, Arthur et al. 1987)		
		96.27			
		137.80			
		54.24			
		97.57			
		212.60	(Wicks and Randall 2002)		
		201.70	(Wicks et al. 2002)		
		31.56			
	✶Chinook salmon, *Oncorhynchus tshawytscha*	79.02	(Thurston and Meyn 1984)		
		62.29			
		83.90			
		111.60	(Servizi and Gordon 1990)		

Notes

✶The *Oncorhynchus tshawytscha* SMAV is 82.39 TAN-mg/L.

5.2.6.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC50:LC5 ratio for chum. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for chum.

5.2.6.3 Calculating Chum Acute Ammonia Minimum Effect Threshold

Dividing the chum LC_{50} (99.15 TAN-mg/L; GMAV, a genus-level surrogate) by the vertebrate acute TAF (1.491) resulted in an acute minimum effect threshold concentration of 66.50 TAN-mg/L (normalized to pH 7).

5.2.6.4 Evaluating Chum Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, chum LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding chum acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in each of the two chum ESU ranges in Washington.

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figures 5-11 to 5-12). Data points above the linear line indicate scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, “nLC_5”, the chum ESU range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and chum acute effect threshold data (i.e., LC_5) are reported in Table 5-19.

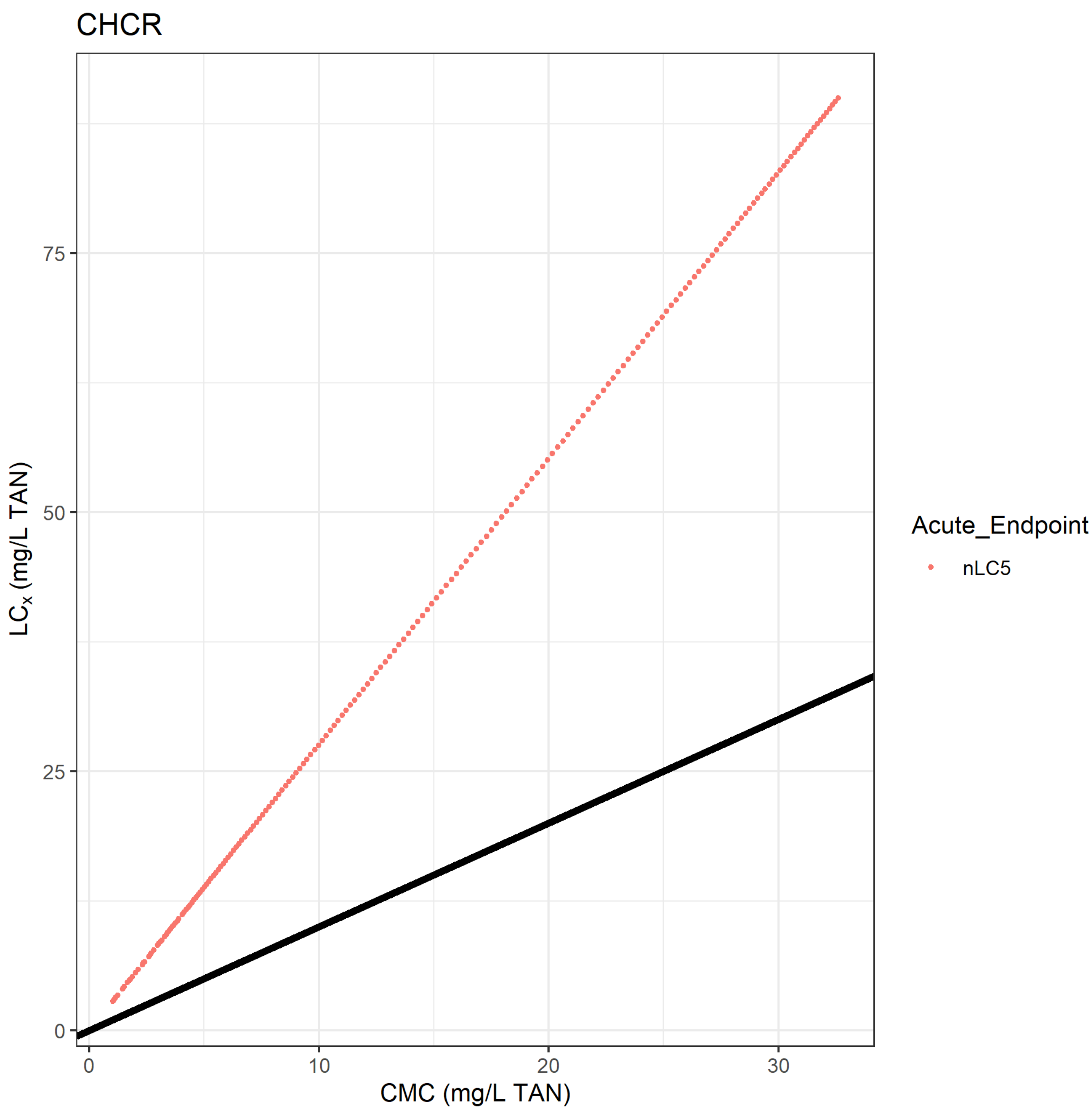

Figure 5-11. Paired chum Columbia River ESU effect concentrations (LC_5) and acute criterion values (CMC) in chum range (n=2900). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

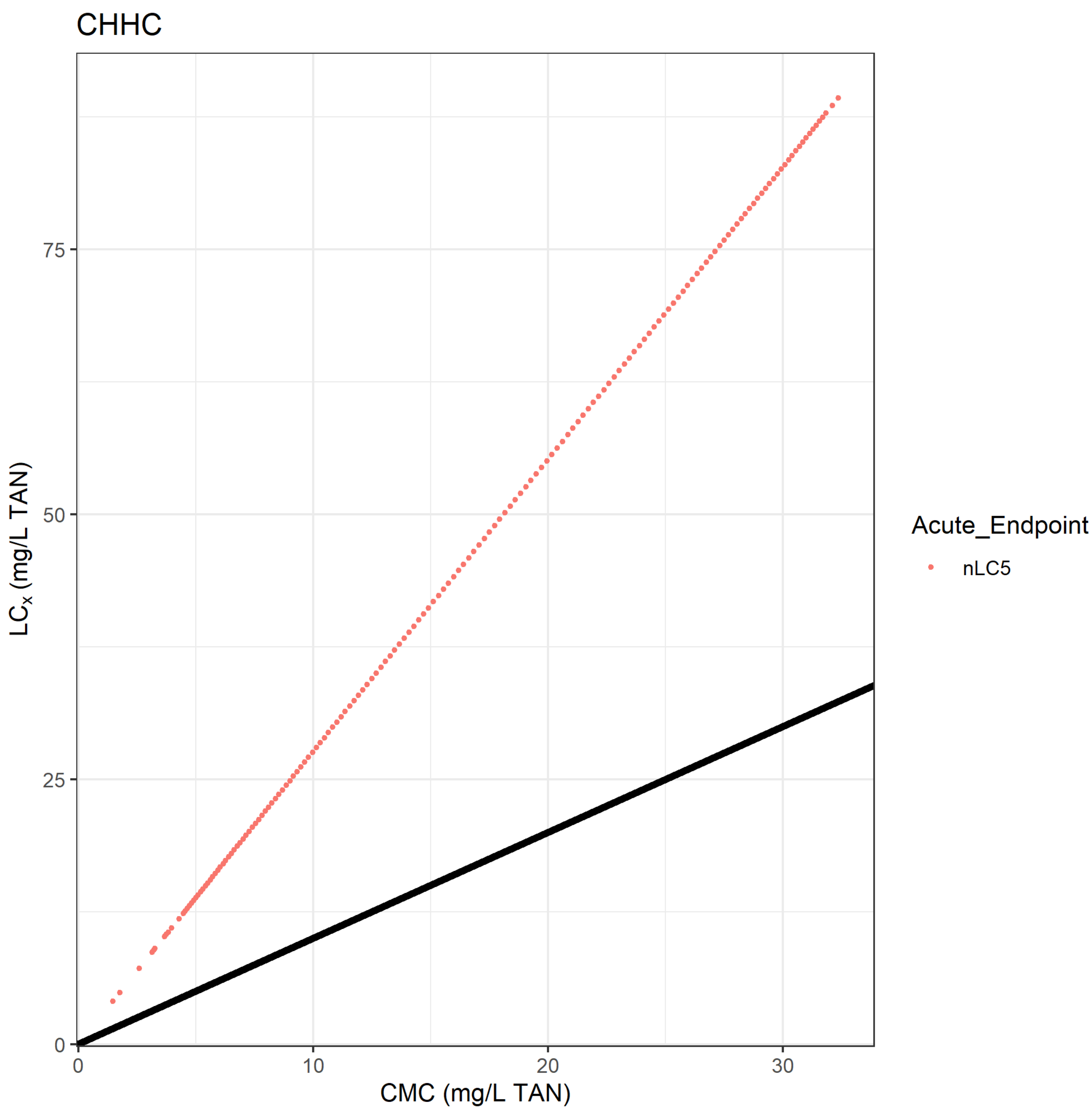

Figure 5-12. Paired chum Columbia River ESU effect concentrations (LC_5) and acute criterion values (CMC) in chum range (n=1485). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

Table 5-19. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the chum acute effect concentrations (LC_5). Comparisons are based only on paired pH and temperature collected from within chum ESU ranges.

Species Name	ESU	Paired pH and Temperature Samples (n)	CMC > LC5	
			n	%
Chum	Columbia River	2900	0	0
	Hood Canal	1485	0	0

5.2.6.5 Chum Salmon: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.1 TAN-mg/L) is 2.76 times lower than the chum salmon acute minimum effect threshold of 66.5 TAN-mg/L, suggesting chum is tolerant to acute ammonia concentrations consistent with the CMC under continuous exposure conditions. Approval of the acute ammonia WQS is Not Likely to Adversely Affect (NLAA) the chum salmon through direct acute effects.

5.2.6.6 Assessment of Effects on Chum Prey

Chum salmon are an anadromous fish species that only inhabit fresh water during a short juvenile stage after hatching in their natal streams. These fish quickly migrate into the marine environment after hatching where they congregate in schools. Prior to migration, chum salmon fry feed on small invertebrates and crustaceans (Behnke 2010). As juveniles, chum salmon feed broadly on benthic invertebrates, including insects, crustaceans, and mollusks (in marine environments) as primary food sources. Adult chum salmon exhibit opportunistic feeding on invertebrates and fishes. They preferentially feed on larger zooplankton over small zooplankton (Higgs et al. 2010). Because of their larger stomach, chum salmon are better able to utilize gelatinous zooplankton more efficiently than other species (NPFMC 2012). As with all anadromous salmonids, the adult salmon will rarely eat as they migrate back to freshwater. Therefore, the chum salmon diet in freshwater will only consist of invertebrate (but not mollusks) items consumed as indicated above.

Table 5-20. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded row indicates the most sensitive potential prey item for chum.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Table 5-20 is the USEPA 2013 ammonia acute criterion dataset. All species in the dataset reflect species or surrogates that represent possible chum prey items. GMAVs (based on LC_{50} values) are at the reference water conditions (pH 7, 20°C). Chum in freshwater feed on insects and crustaceans and do not feed on mussels during their freshwater life stage. The CMC at reference conditions is 24.1 TAN-mg/L while the lowest relevant GMAV is 125.0 TAN-mg/L for water flea. For the reasons presented above, the approval of Washington freshwater acute ammonia WQS is not expected to reduce chum prey availability and is therefore NLAA chum through this pathway.

5.2.7 Coho Salmon (*Oncorhynchus kisuth*) Lower Columbia River ESU

5.2.7.1 Identifying Coho Acute Ammonia Data

High-quality acute toxicity data were available for coho salmon. Therefore, species-level acute toxicity data were used to derive the SMAV, representative of chum salmon sensitivity to acute ammonia exposures. The *Oncorhynchus kisuth* SMAV (87.05 TAN-mg/L, normalized to pH 7) was based on eight tests generating eight LC_{50} values and is considered representative of the coho salmon (Table 5-21).

Table 5-21. Data used to calculate the *Oncorhynchus kisuth* SMAV representative of coho salmon

Species	LC_{50} (TAN-mg/L)[a]	Reference	SMCV (TAN-mg/L)[a]
Coho salmon, *Oncorhynchus kisuth*	102.50	(Wilson 1974, Robinson-Wilson and Seim 1975)	87.05
	60.20	(Buckley 1978)	
	82.02	(Wilson 1974, Robinson-Wilson and Seim 1975)	
	84.43		
	91.90		
	95.73		
	92.84		
	94.44		

5.2.7.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC50:LC5 ratio for coho. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for coho.

5.2.7.3 Calculating Coho Acute Ammonia Minimum Effect Threshold

Dividing the coho LC_{50} (87.05 TAN-mg/L) by the vertebrate acute TAF (1.491) resulted in an acute minimum effect threshold concentration of 58.38 TAN-mg/L (normalized to pH 7).

5.2.7.4 Evaluating Coho (Lower Columbia River ESU) Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, coho LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding coho acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in coho range in Washington.

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figure 5-13). Data points above the linear line indicate scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, “nLC_5”, the coho ESU range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and coho acute effect threshold data (i.e., LC_5) are reported in Table 5-22.

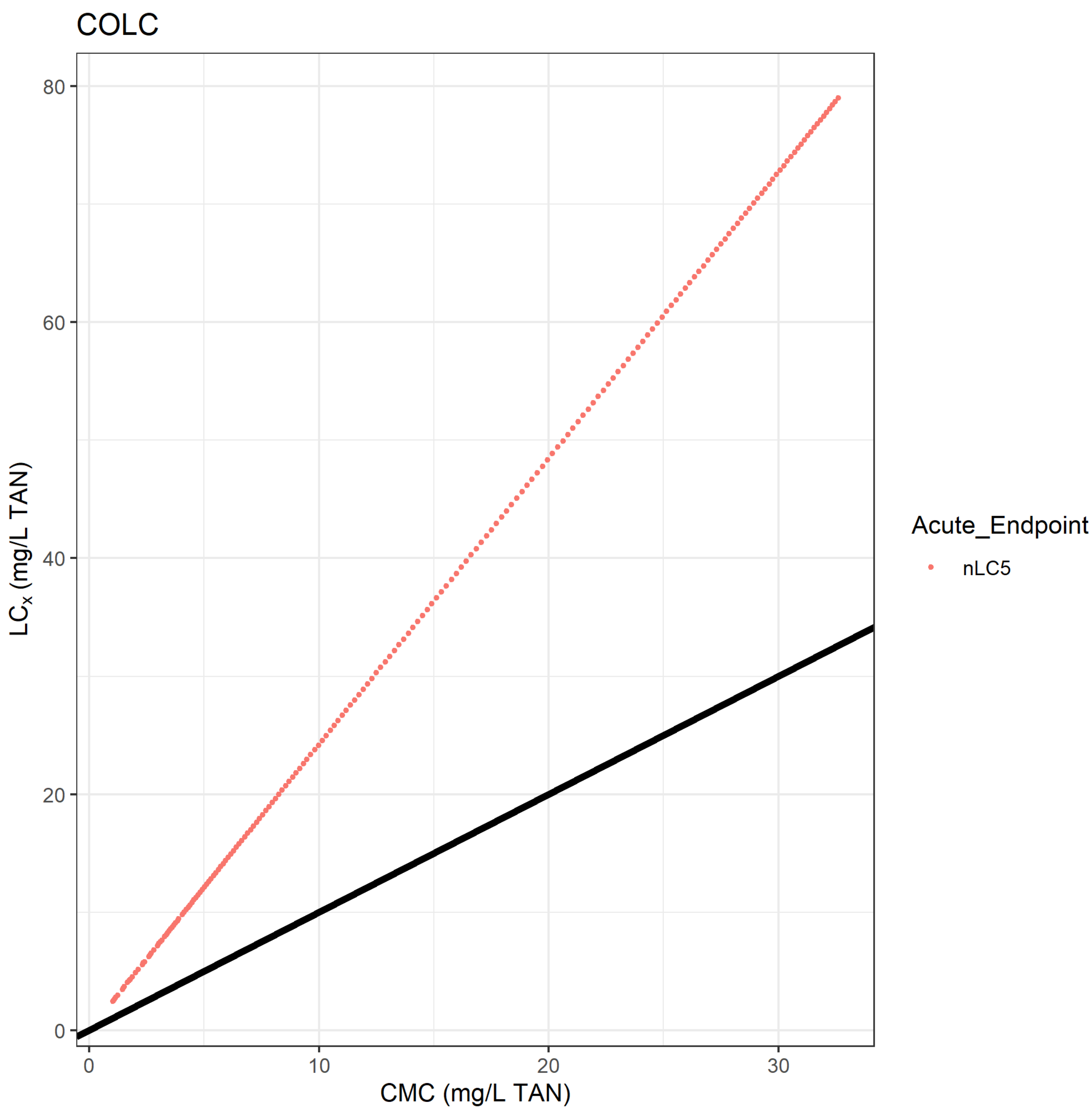

Figure 5-13. Paired coho Lower Columbia River ESU effect concentrations (LC_5) and acute criterion values (CMC) in coho range (n=2977). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

Table 5-22. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the coho acute effect concentrations (LC_5). Comparisons are based only on paired pH and temperature collected from within the coho Lower Columbia River ESU range.

Species Name	ESU	Paired pH and Temperature Samples (n)	CMC > LC_5	
			n	%
Coho salmon	Lower Columbia	2977	0	0

5.2.7.5 Coho Salmon: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.1 TAN-mg/L) is 2.42 times lower than the coho salmon acute minimum effect threshold of 58.38 TAN-mg/L, suggesting coho is tolerant to acute ammonia concentrations consistent with the CMC under continuous exposure conditions. Furthermore, there were no occurrences in coho range in which the CMC was greater than the LC_5. That is, the coho acute minimum effect threshold concentration was greater than the corresponding criterion magnitude in all evaluated conditions. As a result, approval of the acute ammonia WQS is NLAA the coho salmon Lower Columbia River ESU through direct acute effects.

5.2.7.6 Assessment of Effects on Coho Prey

Coho salmon are anadromous fish species but can also live in freshwater rivers and streams, lakes, estuaries and marine environments, depending on life history stage. As juveniles, coho salmon are opportunistic and feed broadly on benthic invertebrates, including insects, crustaceans, and mollusks as primary food sources. Seasonal rainfall plays a factor in the diet of fry in riverine and pond habitats, with large numbers of terrestrial insects (springtails, Isotomidae and Entomobryidae) utilized as prey in early December after heavy rain, and feeding more on benthic invertebrates, such as taeniopterygid nymphs and simuliid larvae in the creek, and chironomid larvae in creeks and ponds, in January when rainfall was low (Minakawa and Kraft 1999). Juvenile coho salmon are opportunistic, however, and have also been shown to feed on adult salmonid carcasses in the winter months (Bilby et al. 1996) (as reported in (Sutherland 2005)). As the fish grow larger, they become increasingly more piscivorous, feeding on smaller pelagic marine fishes (State of California 2004).

Table 5-23. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from USEPA (2013). The green-shaded row indicates the most sensitive potential prey item for chum.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Table 5-23 is the USEPA 2013 ammonia acute criterion dataset. All species in the dataset reflect species or surrogates that represent possible coho prey items. GMAVs (based on LC_{50} values) are at the reference water conditions (pH 7, 20°C). Coho are opportunistic feeders that do not focus on mussels at early or any one life stage. The CMC at reference conditions is 24.1 TAN-mg/L and the lowest two of 69 (just 2.9% of all GMAVs) GMAVs (mussel genera) are 23.12 and 23.41 TAN-mg/L. However, these mussels represent just a fraction of the prey consumed by coho, especially in freshwater versus marine systems. Furthermore, insects, a major food item for coho, are significantly less sensitive to ammonia than mollusks (e.g., lowest GMAV for damselfly, 164.0 TAN-mg/L). For all the reasons presented above, the approval of Washington freshwater acute ammonia WQS is not expected to significantly reduce coho prey availability and is therefore NLAA coho through this pathway.

5.2.8 Sockeye Salmon (*Oncorhynchus nerka*) Snake River and Ozette Lake ESUs

5.2.8.1 Identifying Sockeye Acute Ammonia Data

As data were unavailable for sockeye, data from chum were used as a surrogate for sockeye sensitivity to ammonia. See section 5.2.6.1. and Table 5-18.

5.2.8.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC50:LC5 ratio for sockeye. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for sockeye.

5.2.8.3 Calculating Sockeye Acute Ammonia Minimum Effect Threshold

Dividing the sockeye LC_{50} (99.15 TAN-mg/L) by the vertebrate acute TAF (1.491) resulted in an acute minimum effect threshold concentration of 66.50 TAN-mg/L (normalized to pH 7).

5.2.8.4 Evaluating Sockeye (Snake River and Ozette Lake ESUs) Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, sockeye LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding sockeye acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in both sockeye ESU ranges in Washington. Note that paired water chemistry data were only available for the Snake River ESU; thus, no location specific evaluation was possible for the Ozette Lake ESU.

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figures 5-14). Data points above the linear line indicate scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, "nLC_5", the sockeye ESU range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and sockeye acute effect threshold data (i.e., LC_5) are reported in Table 5-24.

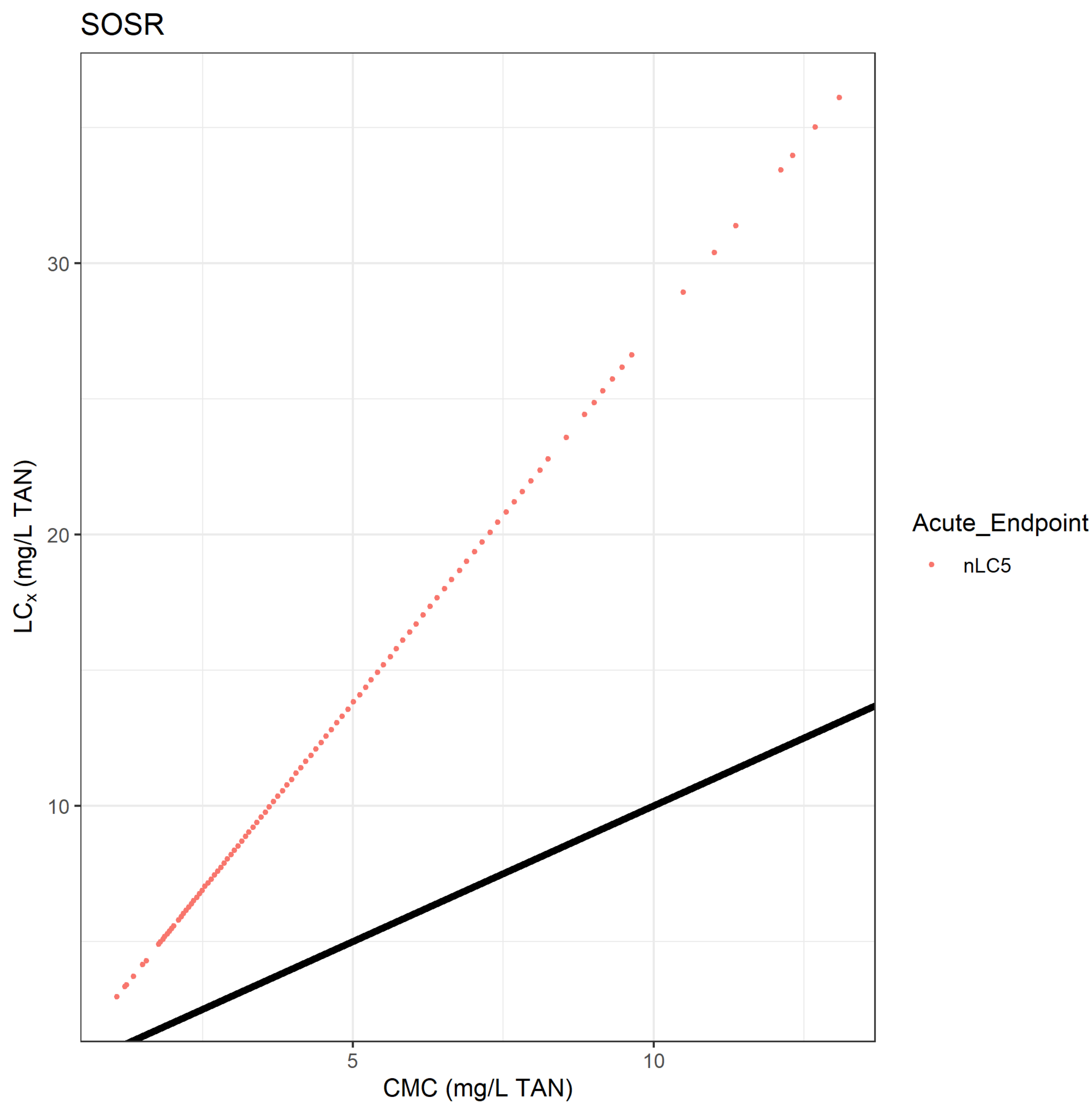

Figure 5-14. Paired sockeye Snake River ESU effect concentrations (LC_5) and acute criterion values (CMC) in sockeye range (n=415). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

Table 5-24. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the sockeye acute effect concentrations (LC_5). Comparisons are based only on paired pH and temperature collected from within the sockeye Snake River ESU range.

Species Name	ESU	Paired pH and Temperature Samples (n)	CMC > LC_5	
			n	%
Sockeye salmon	Snake River	415	0	0
	Ozette Lake	0	NA	NA

5.2.8.5 Sockeye Salmon Snake River and Ozette Lake ESUs: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.1 TAN-mg/L) is 2.76 times lower than the sockeye salmon acute minimum effect threshold of 66.50 TAN-mg/L, suggesting sockeye are tolerant to acute ammonia concentrations consistent with the CMC under continuous exposure conditions. Furthermore, there were no occurrences in sockeye range in which the CMC was greater than the LC_5. That is, the sockeye acute minimum effect threshold concentration was greater than the corresponding criterion magnitude in all evaluated conditions. As a result, approval of the acute ammonia WQS is NLAA the sockeye salmon Snake River and Ozette Lake ESUs through direct acute effects.

5.2.8.6 Assessment of Effects on Sockeye Prey

Sockeye salmon are generally anadromous, but distinct populations of non-anadromous sockeye salmon also exist; these fish are commonly referred to as kokanee (*O. nerka kennerlyi*) or silver trout (Wydoski and Whitney 2003). They display more life history diversity than all other members of the Oncorhynchus genus (Burgner 1991). Juvenile sockeye salmon generally feed on plankton (such as ostracods, cladocerans, and copepods), benthic amphipods, and insects before they migrate to the ocean. In the ocean, they continue to feed on plankton but also prey upon larval and small adult fishes (such as sand lance), and occasionally squid (ADFG 1994).

Table 5-25. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from USEPA (2013). The green-shaded row indicates the most sensitive potential prey item for sockeye.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Table 5-25 is the USEPA 2013 ammonia acute criterion dataset. Only some species in the dataset reflect species or surrogates that represent possible sockeye prey items. GMAVs (based on LC_{50} values) are at the reference water conditions (pH 7, 20°C). Sockeye in freshwater feed on insects and crustaceans and do not readily eat mussels during their freshwater life stage. The CMC at reference conditions is 24.1 TAN-mg/L while the lowest relevant GMAV is 125.0 TAN-mg/L for water flea. For the reasons presented above, the approval of Washington freshwater acute ammonia WQS is not expected to significantly reduce sockeye prey availability and is therefore NLAA sockeye salmon through this pathway.

5.2.9 Chinook Salmon (*Oncorhynchus tshawytscha*) Upper Columbia River Spring-Run, Snake River Spring/Summer Run, Upper Willamette River, Puget Sound, Lower Columbia River ESUs

5.2.9.1 Identifying Chinook Salmon Acute Ammonia Data

Species-level acute toxicity data were used to derive the *Oncorhynchus tshawytscha* SMAV, representative of Chinook salmon sensitivity to acute ammonia exposures. The SMAV (82.39 TAN-mg/L, normalized to pH 7) was based on four LC_{50} values and are considered representative of the Chinook salmon's sensitivity to ammonia. See Table 5-26.

Table 5-26. Data used to calculate the SMAV representative of Chinook salmon

Species	LC_{50} (TAN-mg/L)[a]	Reference	SMAV (TAN-mg/L)[a]
Chinook salmon, *Oncorhynchus tshawytscha*	79.02	(Thurston and Meyn 1984)	82.39
	111.60	(Servizi and Gordon 1990)	

Species	LC_{50} (TAN-mg/L)[a]	Reference	SMAV (TAN-mg/L)[a]
	62.29	(Thurston and Meyn 1984)	
	83.90		

[a] normalized to pH 7

5.2.9.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for deriving an LC50:LC5 ratio for Chinook salmon. Therefore, EPA analyzed quantitatively acceptable C-R data (Appendix B) to calculate vertebrate and invertebrate-level TAFs. The vertebrate TAF was statistically significantly different than the invertebrate TAF. Therefore, the vertebrate TAF 1.491 was used to translate LC_{50} to LC_5 values for Chinook salmon.

5.2.9.3 Calculating Chinook Salmon Acute Ammonia Minimum Effect Threshold

Dividing the Chinook salmon LC_{50} (82.39 TAN-mg/L) by the vertebrate acute TAF (1.491) resulted in an acute minimum effect threshold concentration of 55.26 TAN-mg/L (normalized to pH 7).

5.2.9.4 Evaluating Chinook (all ESUs in Washington) Sensitivity to Ammonia in Washington Surface Freshwaters

To account for the changes in the acute ammonia criterion magnitude and sensitivity across varying water chemistry conditions, Chinook LC_5 values were renormalized to Washington-specific pH and temperature measurements paired in space and time to calculate an acute criterion magnitude and corresponding Chinook acute effect threshold values (i.e., LC_5) for each set of paired water chemistry data in both Chinook ESU ranges in Washington.

To visually display the comparisons, criterion magnitudes (X-axis) and corresponding acute effect concentrations (Y-axis) were plotted over a linear (i.e., 1:1) line (see Figures 5-15 to 5-19). Data points above the linear line indicate scenarios where the CMC was less than the corresponding acute effect threshold data (i.e., Acute Endpoint, "nLC5", the Chinook ESU range specific normalized LC_5) and data points below the 1:1 line would indicate scenarios where the CMC was greater than the corresponding acute effect threshold data. Direct numeric comparisons between the acute criterion magnitudes and Chinook acute effect threshold data (i.e., LC_5) are reported in Table 5-27.

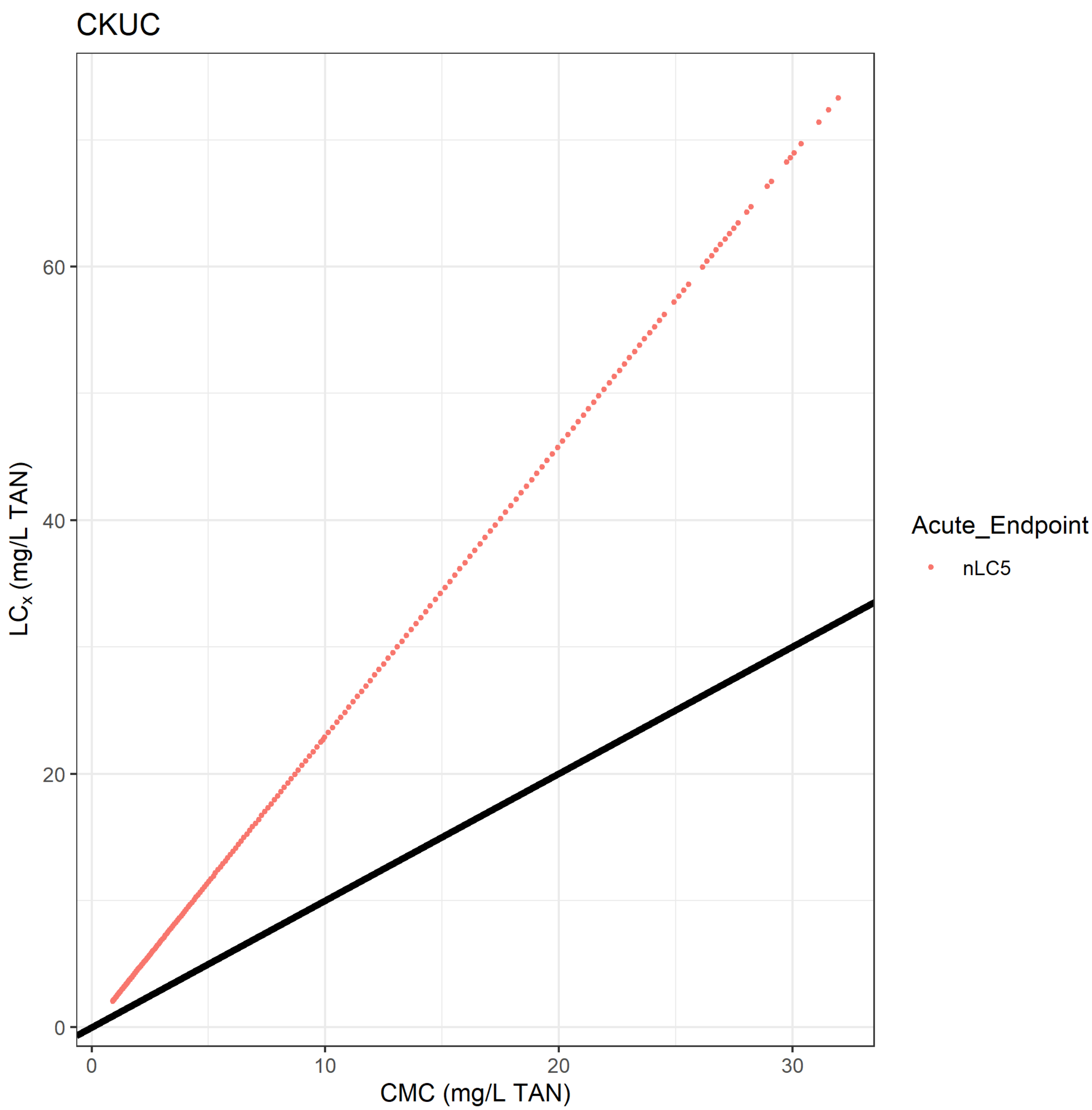

Figure 5-15. Paired Chinook Upper Columbia River Spring Run ESU effect concentrations (LC_5) and acute criterion values (CMC) in Chinook range (n=1668). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

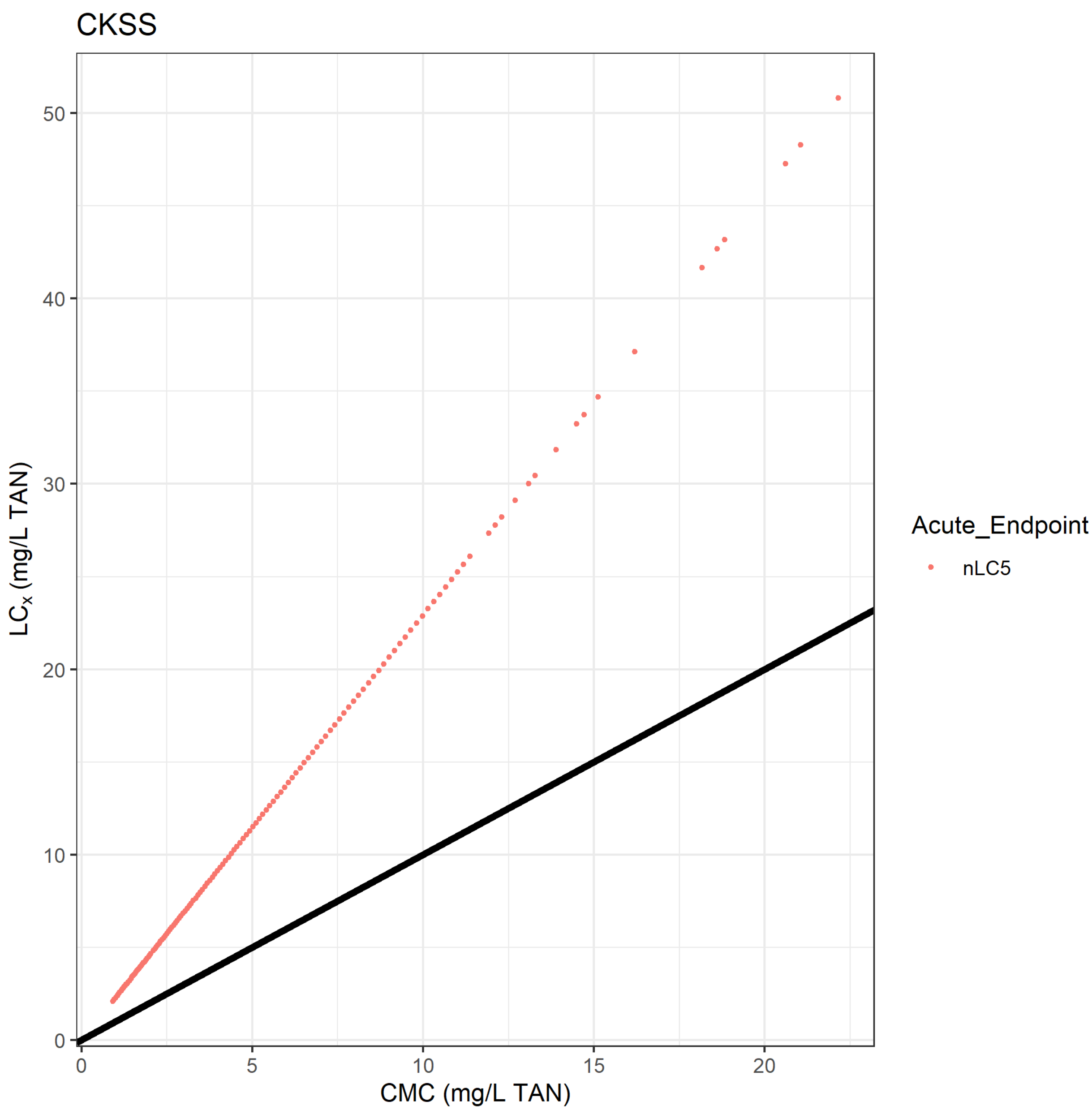

Figure 5-16. Paired Chinook Snake River Spring/Summer Run ESU effect concentrations (LC_5) and acute criterion values (CMC) in Chinook range (n=994). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

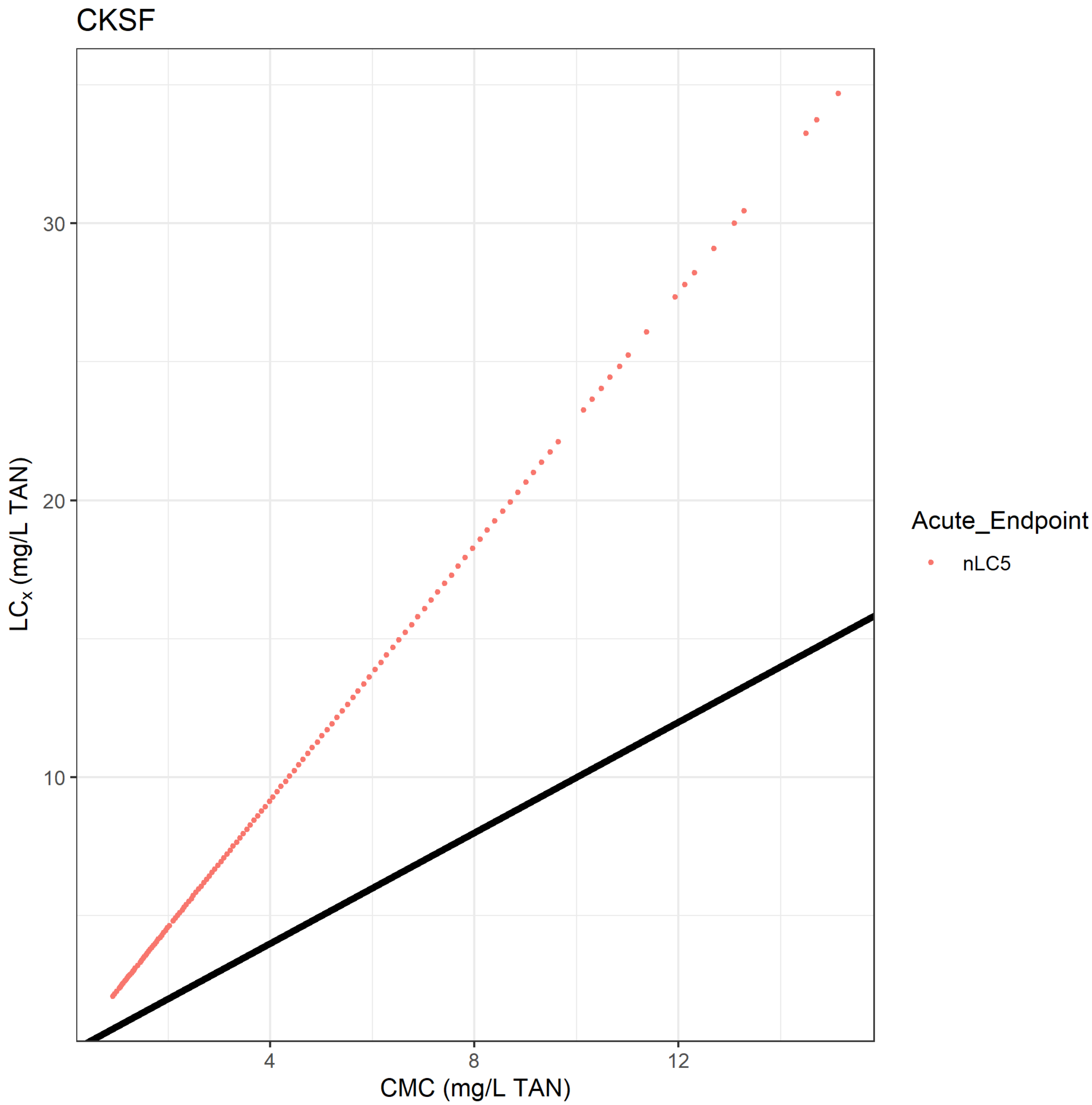

Figure 5-17. Paired Chinook Snake River Fall Run ESU effect concentrations (LC_5) and acute criterion values (CMC) in Chinook range (n=841). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

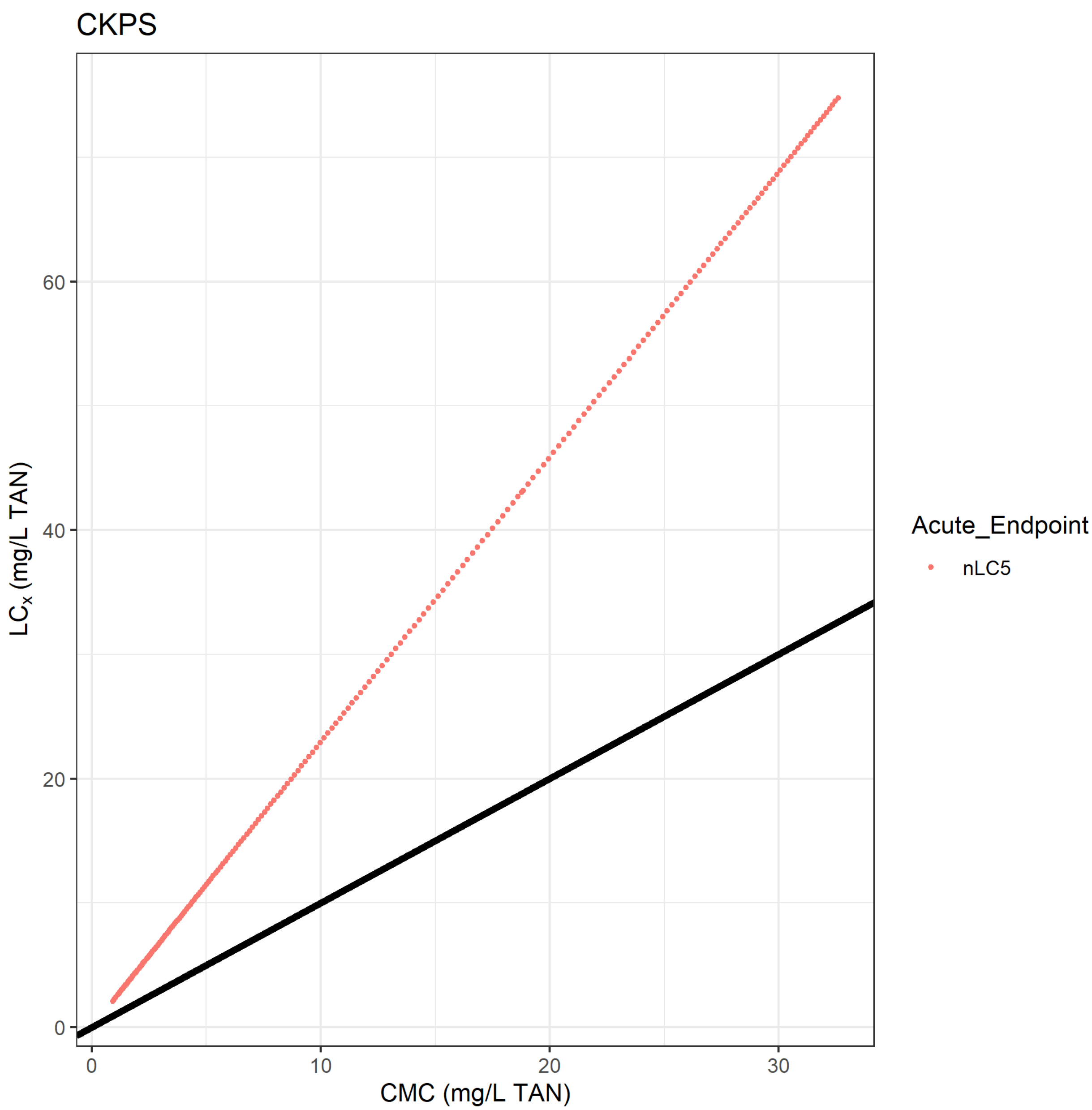

Figure 5-18. Paired Chinook Puget Sound ESU effect concentrations (LC_5) and acute criterion values (CMC) in Chinook range (n=17668). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

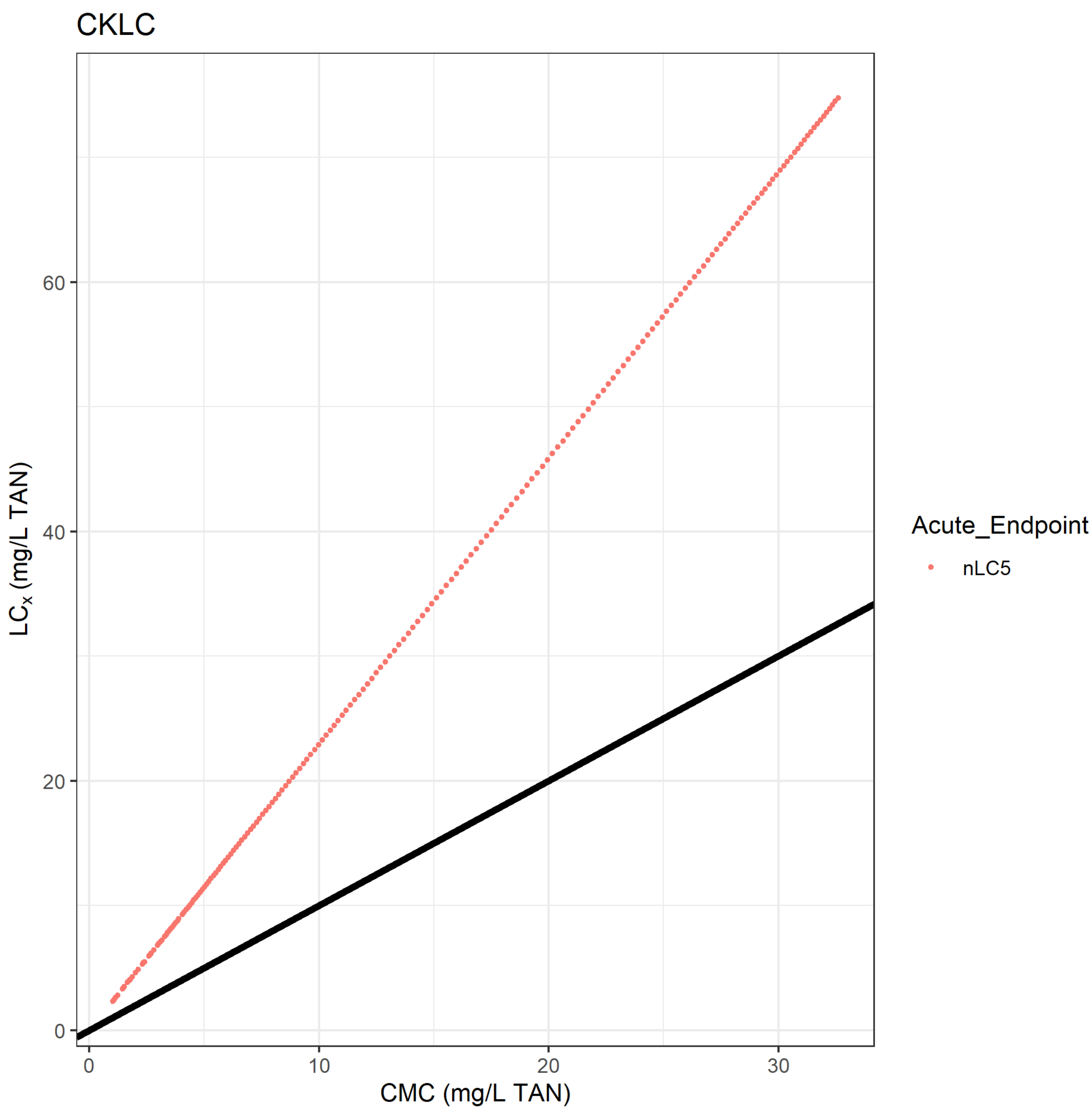

Figure 5-19. Paired Chinook Lower Columbia River ESU effect concentrations (LC_5) and acute criterion values (CMC) in Chinook range (n=2977). The black solid line indicates a slope of 1 and an intercept of 0 to provide context to the relationship between LC_x and CMC values.

Table 5-27. The number (n) and percentage (%) of occurrences in which the acute criterion magnitude exceeded the Chinook acute effect concentrations (LC_5)

Species Name	ESU	Paired pH and Temperature Samples (n)	CMC > LC_5	
			n	%
Chinook salmon	Upper Columbia River Spring Run	1668	0	0
	Snake River Spring/Summer Run	994	0	0
	Snake River Fall Run	841	0	0
	Upper Willamette River	0	NA	NA
	Puget Sound	17,668	0	0
	Lower Columbia River	2977	0	0

5.2.9.5 Chinook Salmon Upper Columbia River Spring Run, Snake River Spring/Summer Run, Upper Willamette River, Puget Sound, and Lower Columbia River ESUs: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (24.1 TAN-mg/L) is 2.29 times lower than the Chinook salmon acute minimum effect threshold of 55.26 TAN-mg/L, suggesting Chinook are tolerant to acute ammonia concentrations consistent with the CMC under continuous exposure conditions. Furthermore, there were no occurrences in Chinook range in which the CMC was greater than the LC_5. That is, the Chinook acute minimum effect threshold concentration was greater than the corresponding criterion magnitude in all evaluated conditions. As a result, approval of the acute ammonia WQS is NLAA the Chinook salmon Upper Columbia River Spring Run, Snake River Spring/Summer Run, Upper Willamette River, Puget Sound, and Lower Columbia River ESUs through direct acute effects.

5.2.9.6 Assessment of Effects on Chinook Prey

Chinook salmon, also called king salmon, are the largest and least abundant species of Pacific salmon. They are anadromous, and as juveniles feed on insect larvae, terrestrial and aquatic invertebrates, and zooplankton when they are in freshwater. As the Chinook salmon begin to age and mature and enter marine waters their diet changes and they begin to eat epipelagic fish such as herring, sand lance, smelt, and, anchovy along with shrimp and squid (Scott and Crossman 1973a).

Table 5-28. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from USEPA (2013). The green-shaded row indicates the most sensitive potential prey item for Chinook.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

Table 5-28 is the USEPA 2013 ammonia chronic criterion dataset. Only some species in the dataset reflect species or surrogates that represent possible Chinook prey items. GMAVs (based on LC_{50} values) are at the reference water conditions (pH 7, 20°C). Chinook in freshwater feed on insects and other invertebrates but do not feed on mussels during their freshwater life stage. The CMC at reference conditions is 24.1 TAN-mg/L while the lowest relevant GMAV is 125.0 TAN-mg/L for water flea. For the reasons presented above, the approval of Washington freshwater acute ammonia WQS is not expected to significantly reduce Chinook prey availability and is therefore NLAA Chinook through this pathway.

5.2.10 Southern Resident Killer Whale (*Orcinus orca*)

5.2.10.1 Direct Toxicity Evaluation for Southern Resident Killer Whale

The action area does not include marine waters and therefore, direct toxic effects of the action on southern resident killer whale (SRKW) were not evaluated. Furthermore, because of the toxic mode of action of ammonia, aquatic-mammal species, which have a thick dermal layer and breath air, are not expected to be sensitive to aqueous ammonia toxicity. In aquatic vertebrates, uptake and excretion of aqueous ammonia occurs as water filters across the gills (Ip et al. 2001). In an aquatic-mammal species, aqueous ammonia exposure through dermal absorption is insignificant. Ammonia exposure is limited to dietary uptake, where the level of exposure is many orders of magnitude lower than for aquatic organisms. It is expected that any excess ammonia ingested through dietary uptake would be excreted as urea through natural biological processes. Because the level of exposure potential through sensitive mechanisms is low, and largely non-existent, for aquatic-mammal species, EPA approval of the Washington freshwater acute ammonia WQS is NLAA the SRKW through direct effects.

5.2.10.2 Assessment of Effects on Southern Resident Killer Whale Prey

As discussed in section 3.2.8, the SRKW primarily consumes Chinook salmon (>85% of their diet), but this proportion varies seasonally depending on the relative availability of Chinook compared to chum and coho (Ford et al. 2016, Hanson et al. 2021). As Chinook availability seasonally declines, coho or chum are taken despite their lower (~1/3) caloric content than Chinook. Despite the shift to salmonids other than Chinook, Chinook abundance is essential and is known to be strongly correlated with SRKW vital rates (PFMC 2020). Therefore, this assessment focuses on Chinook as a conservative approach. However, given similar sensitivity to ammonia across all salmonids (section 5.2.5 – 5.2.9) that use Washington freshwaters, the conclusions would not be any different. Therefore, this analysis is focused on the effects of the action on Chinook availability for SRKW. The conservative premise for the analysis in this section is that juvenile Chinook mortality from exposure to ammonia directly translates to reduced availability of adult Chinook available for SRKW.

Due to limited data, it is difficult to quantify the fraction of the SRKW diet that is composed of Washington-reared Chinook. However, recent information suggests that approximately 55% of the fall diet of SRKW appears to come from Columbia River stocks, ~15% from Puget Sound, and ~5% from outer Washington coast rivers (total Washington stocks = ~75%). This information is a result of a recent analysis of SRKW scat collected in SRKW range and is certainly not conclusive or static but does provide an idea of the potential effect of ammonia (at criteria concentrations in Washington freshwaters) on SRKW prey availability. The analysis assumes that Chinook would be exposed to ammonia at CMC concentrations, which is another conservative assumption. In coordination with NOAA, EPA developed the following means of estimating the effect of the proposed action on SRKW Chinook prey availability.

Summary of conservative assumptions of the analysis shown below:

- SRKW rely only on Chinook salmon with no ability to fill caloric needs from other fish species (salmonids or otherwise)
- Washington freshwaters are continuously at the ammonia CMC concentration
- Only Washington waters affect Chinook in the Columbia River; a river that is also affected by Canada, Idaho, and Oregon water quality.
- Each ESU in Washington contributes to 75% of the SRKW diet

The following calculation was used to estimate lost prey availability to SRKW.

Lost Salmon Availability (A) = X * Y * Z

Where,

A = % reduction in Chinook availability

X = % reduction in Chinook abundance when CMC = $LC_{05,\ Chinook}$

Y = % Washington water sample locations in which CMC ≥ $LC_{05, \text{Chinook}}$

Z = % of SRKW diet composed of Washington Chinook stocks

Table 5-29 provides the analysis and results for each Chinook Salmon ESU in Washington.

Table 5-29. Estimated percent lost prey availability (A) for SRKW that may use Chinook salmon affected by ammonia in Washington waters, given the percent reduction in salmon abundance when CMC ≥ LC_5 (X), percent Washington water sample locations that CMC = LC_5 (Y), and percent of SRKW diet composed of Washington Chinook stocks (Z). A = X*Y*Z.

Chinook Salmon ESU	X (%)	Y (%)	Z (%)	A (%)
Puget Sound	0.05	0	15	0
Upper Columbia River Spring Run	0.05	0	55	0
Snake River Spring/Summer Run	0.05	0	55	0
Upper Willamette River	0.05	NA	NA	NA
Lower Columbia River	0.05	0	55	0
All	0.05	0	70	0

[NA] Juvenile Chinook of the Upper Willamette River ESU are primarily affected by Oregon water quality, making it highly uncertain to estimate Y and Z. Note that Y would very likely be 0%, given the results for the other ESUs (i.e., CMC < LC05 for all samples)

The estimated lost prey availability by ESU and cumulatively is shown in Table 5-X and indicates that the action would result in a 0% loss in prey availability for SRKW. For the reasons presented above, the approval of Washington freshwater acute ammonia standard is not expected to significantly reduce SRKW prey availability and is therefore NLAA SRKW through this pathway.

5.2.11 Marbled Murrelet (*Brachyramphus marmoratus*)

5.2.11.1 Direct Toxicity Evaluation for Marbled Murrelet

Marbled murrelet is an aquatic-dependent species that primarily feeds on fish and invertebrates (e.g., euphausiids) in marine waters, but there are occasions (e.g., spring-summer breeding season) during which freshwater fish and invertebrates are sought (See section 3.1.1). During feeding, marbled murrelet may be incidentally exposed to freshwater resulting in minimal oral exposure. Limited dermal exposure to freshwaters is also possible during feeding bouts. However, marbled murrelet respiratory surfaces (i.e., the lung) are not in direct contact with water. In an avian species like marbled murrelet, aqueous ammonia exposure through dermal absorption and respiratory exposure is likely to be insignificant. It is expected that any excess ammonia ingested through dietary uptake would be excreted as urea through natural biological processes. Because the level of exposure of susceptible anatomic structures (e.g., lung) is expected to be low or non-existent for avian species, EPA’s approval of the Washington freshwater acute ammonia WQS is NLAA the marbled murrelet through direct effects.

5.2.11.2 Assessment of Effects on Marbled Murrelet Prey

Marbled murrelets spend most of their lives in the marine environment where they forage in near-shore areas and consume a diversity of prey species, including small fish and invertebrates. Marbled murrelets are considered opportunistic feeders rather than specialists (Sanger 1987b) (Burkett 1995b)and seem to prefer euphausiids in spring and fish in summer. Consumption of forage fish coincides with nestling and fledgling periods (Carter and Sealy 1986a). Pacific sand lance are the most important prey species in summer, followed by northern anchovy, Pacific herring, osmerids (capelin and surf smelt), and seaperch. Marbled murrelets also feed on Pacific sardine, walleye pollock, rockfish, and squid during breeding season. Euphausiids are key prey in spring (Sealy 1975c), and during breeding season in some years (L. Krasnow and G. Sanger unpubl. data). Euphausiids, mysids, gammarids (amphipods), osmerids, and herring are dominant prey in winter (Munro and Clemens 1931, Sanger 1987b, Vermeer 1992). Marbled murrelets also feed on rockfish, squid, and shrimp during winter and on salmon (sockeye and Kokanee) in freshwater lakes, primarily in summer (Carter and Sealy 1986a).

As a result of the potential for prey to be affected by ammonia in freshwater and thus prey availability for marbled murrelet, EPA evaluated the toxicity of ammonia to surrogate prey items. Table 5-30 is the USEPA 2013 ammonia chronic criterion dataset to show species or surrogates that represent possible murrelet prey items. The most sensitive potential prey item (i.e., lowest GMAV) is noted by green shading. All other potential prey items would therefore be less sensitive than the green-shaded cells and have higher GMAVs. GMAVs are based on LC_{50} values are at reference water conditions (pH 7).

Table 5-30. Ranked genus mean acute values (GMAV) and associated species mean acute values (SMAV) from EPA 2013. The green-shaded row indicates the most sensitive potential prey item for marbled murrelet.

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
69	2515	Insect, *Erythromma najas*	2515
68	994.5	Caddisfly, *Philarctus quaeris*	994.5
67	735.9	Beetle, *Stenelmis sexlineata*	735.9
66	686.2	Crayfish, *Orconectes immunis*	1550
		Crayfish, *Orconectes nais*	303.8
65	681.8	Midge, *Chironomus riparius*	1029
		Midge, *Chironomus tentans*	451.8
64	442.4	Mayfly, *Drunella grandis*	442.4
63	387.0	Aquatic sowbug, *Caecidotea racovitzai*	387.0

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
62	378.2	Isopod, *Asellus aquaticus*	378.2
61	281.5	Threespine stickleback, *Gasterosteus aculeatus*	281.5
60	246.5	Mayfly, *Callibaetis skokianus*	364.6
		Mayfly, *Callibaetis* sp.	166.7
59	233.0	Dragonfly, *Pachydiplax longipennis*	233.0
58	222.2	Mottled sculpin, *Cottus bairdii*	222.2
57	219.3	Western mosquitofish, *Gambusia affinis*	219.3
56	218.7	Oligochaete worm, *Lumbriculus variegatus*	218.7
55	216.5	Tubificid worm, *Tubifex tubifex*	216.5
54	211.6	Marsh ramshorn snail, *Planorbella trivolvis*	211.6
53	192.6	Scud, *Hyalella azteca*	192.6
52	192.4	Stonefly, *Skwala americana*	192.4
51	185.2	Mozambique tilapia, *Oreochromis mossambicus*	185.2
50	181.8	Amphipod, *Crangonyx pseudogracilis*	270.5
		Amphipod, *Crangonyx* sp.	122.2
49	170.2	Tubificid worm, *Limnodrilus hoffmeisteri*	170.2
48	164.5	Pouch snail, *Physa gyrina*	164.5
47	164.0	Damselfly, *Enallagma* sp.	164.0
46	162.6	Water flea, *Chydorus sphaericus*	162.6
45	159.2	Fathead minnow, *Pimephales promelas*	159.2
44	157.8	Brook trout, *Salvelinus fontinalis*	156.3
		Lake trout, *Salvelinus namaycush*	159.3

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
43	156.7	Shortnose sturgeon, *Acipenser brevirostrum (LS)*	156.7
42	146.5	White sucker, *Catostomus commersonii*	157.5
		Mountain sucker, *Catostomus platyrhynchus*	136.2
41	143.9	Water flea, *Ceriodaphnia acanthine*	154.3
		Water flea, *Ceriodaphnia dubia*	134.2
40	142.9	Water flea, *Simocephalus vetulus*	142.9
39	142.4	Channel catfish, *Ictalurus punctatus*	142.4
38	138.0	Red swamp crayfish, *Procambarus clarkii*	138.0
37	136.7	Atlantic salmon, *Salmo salar (LS)*	183.3
		Brown trout, *Salmo trutta*	102.0
36	134.8	White perch, *Morone americana*	132.7
		White bass, *Morone chrysops*	144.0
		Striped bass, *Morone saxatilis*	246.2
		Sunshine bass, *Morone saxatilis x chrysops*	70.22
35	125.0	Water flea, *Daphnia magna*	157.7
		Water flea, *Daphnia pulicaria*	99.03
34	122.5	Clawed toad, *Xenopus laevis*	122.5
33	119.5	Flatworm, *Dendrocoelum lacteum*	119.5
32	117.1	Walleye, *Sander vitreus*	117.1
31	115.9	Central stoneroller, *Campostoma anomalum*	115.9
30	110.0	Rainbow dace, *Cyprinella lutrensis*	196.1
		Spotfin shiner, *Cyprinella spiloptera*	83.80

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Steelcolor shiner, *Cyprinella whipplei*	80.94
29	109.0	Dwarf wedgemussel, *Alasmidonta heterodon (LS)*	109.0
28	109.0	Pink papershell, *Potamilus ohiensis*	109.0
27	106.9	Green sunfish, *Lepomis cyanellus*	150.8
		Pumpkinseed, *Lepomis gibbosus*	77.53
		Bluegill, *Lepomis macrochirus*	104.5
26	106.3	Common carp, *Cyprinus carpio*	106.3
25	99.15	Golden trout, *Oncorhynchus aguabonita*	112.1
		Cutthroat trout, *Oncorhynchus clarkii*	78.92
		Pink salmon, *Oncorhynchus gorbuscha*	180.7
		Coho salmon, *Oncorhynchus kisutch (LS)*	87.05
		Rainbow trout, *Oncorhynchus mykiss (LS)*	82.88
		Chinook salmon, *Oncorhynchus tshawytscha (LS)*	82.39
24	96.72	Topeka shiner, *Notropis topeka (LS)*	96.72
23	96.38	Leopard frog, *Rana pipiens*	96.38
22	89.36	Long fingernailclam, *Musculium transversum*	89.36
21	89.06	Smallmouth bass, *Micropterus dolomieu*	150.6
		Largemouth bass, *Micropterus salmoides*	86.02
		Guadalupe bass, *Micropterus treculii*	54.52
20	88.62	Great pond snail, *Lymnaea stagnalis*	88.62
19	74.66	Guppy, *Poecilia reticulata*	74.66
18	74.25	Johnny darter, *Etheostoma nigrum*	71.45

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
		Orangethroat darter, *Etheostoma spectabile*	77.17
17	72.55	Rio Grande silvery minnow, *Hybognathus amarus*	72.55
16	71.56	Spring peeper, *Pseudacris crucifer*	61.18
		Pacific tree frog, *Pseudacris regilla*	83.71
15	71.25	Mucket, *Actinonaias ligamentina*	63.89
		Pheasantshell, *Actinonaias pectorosa*	79.46
14	70.73	Giant floater mussel, *Pyganodon grandis*	70.73
13	69.36	Shortnose sucker, *Chasmistes brevirostris*	69.36
12	68.54	Pagoda hornsnail, *Pleurocera uncialis*	68.54
11	63.02	Golden shiner, *Notemigonus crysoleucas*	63.02
10	62.15	Pebblesnail, *Fluminicola* sp.	62.15
9	56.62	Lost River sucker, *Deltistes luxatus(LS)*	56.62
8	51.93	Mountain whitefish, *Prosopium williamsoni*	51.93
7	47.40	Atlantic pigtoe, *Fusconaia masoni*	47.40
6	46.93	Pondshell mussel, *Utterbackia imbecillis*	46.93
5	46.63	Pink mucket, *Lampsilis abrupta (LS)*	26.03
		Plain pocketbook, *Lampsilis cardium*	50.51
		Wavy-rayed lampmussel, *Lampsilis fasciola*	48.11
		Higgin's eye, *Lampsilis higginsii (LS)*	41.90
		Neosho mucket, *Lampsilis rafinesqueana (LS)*	69.97
		Fatmucket, *Lampsilis siliquoidea*	55.42
4	34.23	Rainbow mussel, *Villosa iris*	34.23

Rank	GMAV (TAN-mg/L)	Species	SMAV (TAN-mg/L)
3	31.14	Oyster mussel, *Epioblasma capsaeformis (LS)*	31.14
2	23.41	Green floater, *Lasmigona subviridis*	23.41
1	23.12	Ellipse, *Venustaconcha ellipsiformis*	23.12

As marbled murrelet primarily consume fish in freshwaters, the lowest potentially relevant GMAV at pH 7 is 51.93 TAN-mg/L (Mountain whitefish) whereas the CMC at those same normalized conditions is 24.1 TAN-mg/L. Further, marbled murrelet have been shown to focus freshwater foraging on salmonids (see above), which are less sensitive than Mountain whitefish, with an *Oncorhynchus* GMAV of 99.15 TAN-mg/L. As a result, EPA approval of Washington's freshwater acute ammonia WQS is NLAA marbled murrelet through a reduction in prey availability.

5.3 Weight of Evidence Calculations and Summary of Species Effects Determinations

As shown in figure 5-1, multiple LOEs were weighted to determine the effects of the action on species in the action area. The information provided in section 5.2 provide the basis for the calculations shown in figure 5-20 below and in Attachment 1.

	Relative Weights	Max Points	Green sturgeon	Eulachon	Coho-LCR	Chum-CR	Chum-HCS	Chinook-UCRS	Chinook-SRSS	Chinook-SRF	Chinook-UWR	Chinook-PS	Chinook-LC	Sockeye-SR	Sockeye-OL	Steelhead-UCR	Steelhead-SRB	Steelhead-MC	Steelhead-UWR	Steelhead-PS	Steelhead-LCR	SRKW	OR spotted frog	Bull trout	Marbled murrelet
LOE1	0.75	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOE2	0.10	4																							
LOE3	0.15	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total points		12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Score		4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Possible Score		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
WOE Score		100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Interpretation		High	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA	NLAA

Key for Figure 5-20

Line of Evidence (LOE)	LAA interpretation	Point scale
LOE1 = Direct toxicity	High LAA = 76-100%	4 = high evidence for LAA
LOE2 = exposure analysis	Moderate LAA = 51-75%	3 = moderate evidence for LAA
LOE3 = indirect effects analysis (effects on prey base)	Low LAA = 26-50%	2 = low evidence for LAA
	Very Low LAA = 1-25%	1 = very low evidence for LAA
	NLAA = 0%	0 = no evidence for LAA

Figure 5-20. Summary of weight of evidence (WOE) calculations to determine the effects of the action on species in the action area. LOE2 cells are blank because LOE1 cells are all 0 (i.e., all species LC5 values were greater than the CMC in Washington fresh surface waters).

5.4 Additional Qualitative Considerations in the Evaluation of the Effects (direct toxicity) of the Action

As discussed in sections 1.2 and 5.1.2, acute water quality criteria include three elements. These elements include magnitude, frequency, and duration. Because this BE evaluated only the magnitude element, it was therefore inherently assuming that all surface freshwaters of the state of Washington may contain TAN concentrations at the CMC (the authorized TAN concentration). However, the one-hour average TAN concentration is not to exceed the criterion magnitude more than once every three years (at a permitted location). Therefore, the analysis in this BE is inherently conservative because acute toxicity testing involves continuous TAN exposures for 48 to 96 hours. As exposure duration is known to increase the toxicity of ammonia (Milne et al. 2000), an LC_{50} derived from a 96-hour test is likely to be lower than an LC_{50} after a one-hour exposure (the criteria duration element). Thus, the 48 or 96 hour exposure based LC_{50}'s (converted to LC_5's) used in this BE may overestimate the toxicity an animal would experience after a one-hour exposure (i.e., a higher LC_{50} may be expected with a shorter exposure duration). From this information, it may be concluded that the magnitude and duration elements of the criteria work together to limit adverse effects to aquatic life as the criteria are implemented into permits and other activities in Washington state.

5.5 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

5.5.1 Green Sturgeon (*Acipenser medirostris*) Critical Habitat

As described in section 3.0, the following PBFs are most relevant to the Agency's action for freshwater and estuarine green sturgeon habitats:

- Abundant prey for all life stages; and
- Suitable water quality (i.e., temperature, salinity, dissolved oxygen, and "other chemical characteristics") for normal behavior, growth, and viability of all life stages;

As described in section 5.2.1.5, the Agency's action is not likely to adversely affect water quality for the survival of green sturgeon (assessed via the direct effects analysis). Furthermore, indirect effects of the action on green sturgeon prey may be affected but not at a level expected to induce a significant reduction in prey availability (section 5.2.1.6). Therefore, given no expected direct effects to green sturgeon through impacts on water quality, the EPA has determined that the Agency's action is NLAA the designated critical habitat for Green Sturgeon.

5.5.2 Oregon Spotted Frog (*Rana pretiosa*) Critical Habitat

As described in section 3, PBFs for all areas designated as critical habitat for Oregon spotted frog that are most relevant to the Agency's action include increased sedimentation, increased water temperatures, reduced water quality, and vegetation changes resulting from the timing and intensity of livestock grazing (or, in some instances, removal of livestock grazing at locations where it maintains early seral stage habitat essential for breeding) and inadequate existing regulatory mechanisms that result in significant negative impacts such as habitat loss and modification.

As described in section 5.2.2.5, the Agency's action may affect but is not likely to adversely affect Oregon spotted frog PBFs for reduced water quality/negative impacts to habitat/modification (direct effects), likewise the Agency's action may affect but is NLAA designated critical habitat for Oregon spotted frog.

5.5.3 Eulachon *(Thaleichthys pacificus*) Critical Habitat

As described in section 3, the PBFs for eulachon for freshwater spawning and incubation sites include water flow, quality, and temperature conditions; spawning and incubation substrates; and migratory access. PBFs for freshwater and estuarine migration corridors include waters free of obstruction; specific water flow, quality, and temperature conditions (for supporting larval and adult mobility); and abundant prey items (for supporting larval feeding after the yolk sac is depleted).

The PBFs that may be affected by this action include (1) water quality for freshwater spawning and incubation sites, (2) water quality for freshwater and estuarine migration corridors, and (3) abundant prey items. As described in section 5.2.3.5, this action is not likely to adversely affect the growth, health, migration, and propagation of eulachon through increases in fry mortality (assessed via the direct effects analysis). Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for eulachon.

5.5.4 Bull trout (*Salvelinus confluentus*) Critical Habitat

As described in section 3, the PBFs for Bull trout critical habitat that are most relevant to the Agency's action include migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers; an abundance of food, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish; and, sufficient water quality and quantity to sustain normal reproduction, growth, and survival.

As described in section 5.2.4.5, bull trout are not likely to be adversely affected by the Agency's action. As a consequence, no adverse effects are expected to water quality and thus no adverse effects are expected to bull trout growth, reproduction, survival, migration, spawning, rearing, overwintering, and foraging habitats. In addition, there are no likely adverse effects to the abundance of bull trout prey (section 5.2.4.6). Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for Bull trout.

5.5.5 Steelhead (*Oncorhynchus mykiss*) Critical Habitat for Lower Columbia River, Middle Columbia River, Puget Sound, Snake River, Upper Columbia River, and Upper Willamette ESUs

The PBFs for steelhead are the same for all ESUs, and they are described in Table 3-1 and 3-3. The PBFs that may be affected by the Agency's action include water quality protective of freshwater spawning, freshwater rearing, and freshwater migration. As described in section

5.2.5.5, all steelhead ESUs are not likely to be adversely affected by the Agency's action through impacts to water quality for freshwater spawning, rearing and migration (assessed via the direct effects analysis). Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for all steelhead ESUs.

5.5.6 Chum Salmon (*Oncorhynchus keta*) Critical Habitat for Hood Canal Summer Run and Columbia River ESUs

The PBFs for chum are the same for all ESUs, and they are described in Table 3-1. The PBFs that may be affected by the Agency's action include water quality protective of freshwater spawning, freshwater rearing, and freshwater migration. As described in section 5.2.6.5, all chum ESUs are not likely to be adversely affected by the Agency's action through impacts to water quality for freshwater spawning, rearing and migration. Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for all chum ESUs.

5.5.7 Coho Salmon (*Oncorhynchus kisuth*) Critical Habitat for Lower Columbia River ESU

The PBFs for coho salmon are the same for all ESUs, and they are described in Table 3-1. The PBFs that may be affected by the Agency's action include water quality protective of freshwater spawning, freshwater rearing, and freshwater migration. As described in section 5.2.7.5, the coho Lower Columbia River ESU is not likely to be adversely affected by the Agency's action through impacts to water quality for freshwater spawning, rearing and migration. Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for the coho Lower Columbia River ESU.

5.5.8 Sockeye Salmon (*Oncorhynchus nerka*) Critical Habitat for Snake River and Ozette Lake ESUs

The PBFs for sockeye are described in Table 3-1. The PBFs that may be affected by the Agency's action include water quality protective of freshwater spawning, freshwater rearing, and freshwater migration. As described in section 5.2.8.5, sockeye are not likely to be adversely affected by the Agency's action through impacts to water quality for freshwater spawning, rearing and migration. Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for sockeye salmon Snake River and Ozette Lake ESUs.

5.5.9 Chinook Salmon (*Oncorhynchus tshawytscha*) Critical Habitat for Upper Columbia River Spring-Run, Snake River Spring/Summer Run, Upper Willamette River, Puget Sound, Lower Columbia River ESUs

The PBFs for Chinook are the same for all ESUs, and they are described in Table 3-1 and 3-2. The PBFs that may be affected by the Agency's action include water quality protective of freshwater spawning, freshwater rearing, and freshwater migration. As described in section 5.2.9.5, all Chinook ESUs are not likely to be adversely affected by the Agency's action through impacts to water quality for freshwater spawning, rearing and migration. Therefore, the EPA has determined that the Agency's action is NLAA the designated critical habitat for Chinook salmon

Upper Columbia River Spring-Run, Snake River Spring/Summer Run, Upper Willamette River, Puget Sound, Lower Columbia River ESUs.

5.5.10 Southern Resident Killer Whale (*Orcinus orca*) Critical Habitat

5.5.10.1 Designated Critical Habitat (Summer Core Area, Puget Sound Area and Strait of Juan de Fuca Area)

Because the "quantity and quality of prey" PBF for SRKW is not likely to be adversely affected per section 5.2.10.2, the Agency finds that the Agency's action is NLAA designated SRKW critical habitat.

5.5.10.2 Proposed Critical Habitat (Coastal Area) (Conference Opinion)

Because the "quantity and quality of prey" PBF for SRKW is not likely to be adversely affected per section 5.2.10.2, the Agency finds that the Agency's action is NLAA proposed SRKW critical habitat.

5.5.11 Marbled Murrelet (*Brachyramphus marmoratus*) Critical Habitat

The PBFs for marbled murrelet include individual trees with potential nesting platforms and forested areas within 0.8 km (0.5 miles) of individual tress with potential nesting platforms, and with a canopy height of at least one-half the site-potential tree height. As the action does not involve effects to trees or terrestrial habitat, there is No Effect to marbled murrelet critical habitat.

6. Final Effects Determinations

All listed animals and plants occurring in Washington freshwaters are insensitive to acute freshwater ammonia exposures at the criteria magnitudes under conservative exposure conditions. Aquatic-dependent wildlife were either tolerant to ammonia criteria magnitudes (because they do not possess gills) or will not be exposed to ammonia in the water column (because they do not submerge themselves in the water column). Furthermore, no aquatic or aquatic-dependent listed species will be indirectly affected by ammonia at the acute criteria magnitudes because their prey items are relatively tolerant to ammonia and/or they also prey on a broader variety of food resources that will not be affected or exposed to ammonia in the water column. Approval of the freshwater acute ammonia criteria as a Washington state water quality standards is Not Likely to Adversely Affect aquatic and aquatic-dependent listed species in Washington through direct and/or indirect biological effects (Table 6-1).

Table 6-1. Final effect determinations for aquatic and aquatic-dependent listed species and their critical habitat occurring in Washington that may be affected by the approval action

Species	DPS/ESU	Final Effects Determinations	
		Species	Critical Habitat
USFWS Managed Species			
Marbled murrelet (*Brachyramphus marmoratus*)	Not Applicable	NLAA[a]	NLAA
Oregon spotted frog (*Rana pretiosa*)	Not Applicable	NLAA	NLAA
Bull trout (*Salvelinus confluentus*)	Not Applicable	NLAA	NLAA
NOAA Fisheries Managed Species			
Green sturgeon (*Acipenser medirostris*)	Southern DPS	NLAA	NLAA
Eulachon (*Thaleichthys pacificus*)	Southern DPS	NLAA	NLAA
Steelhead (*Oncorhynchus mykiss*)	Upper Columbia River	NLAA	NLAA
	Snake River Basin	NLAA	NLAA
	Middle Columbia River	NLAA	NLAA
	Upper Willamette River	NLAA	NLAA
	Puget Sound	NLAA	NLAA
	Lower Columbia River	NLAA	NLAA
Chum salmon (*Oncorhynchus keta*)	Columbia River	NLAA	NLAA
	Hood Canal, summer run	NLAA	NLAA
Coho salmon (*Oncorhynchus kisutch*)	Lower Columbia River	NLAA	NLAA
Sockeye salmon (*Oncorhynchus nerka*)	Snake River	NLAA	NLAA
	Ozette Lake	NLAA	NLAA

Species	DPS/ESU	Final Effects Determinations	
		Species	Critical Habitat
Chinook salmon (*Oncorhynchus tshawytscha*)	Upper Columbia River, spring-run	NLAA	NLAA
	Snake River spring/summer-run	NLAA	NLAA
	Snake River Fall-run	NLAA	NLAA
	Upper Willamette River	NLAA	NLAA
	Puget Sound	NLAA	NLAA
	Lower Columbia River	NLAA	NLAA
Killer whale (*Orcinus orca*)	Southern Resident	NLAA	NLAA[b]
			NLAA[c]

[a] NLAA: Not Likely to Adversely Affect
[b] Effect determination for Designated Critical Habitat
[c] Effect determination for Proposed Coastal Area Critical Habitat

7. Essential Fish Habitat

In this section, Essential Fish Habitat (EFH) is assessed for potential adverse impacts from the USEPA's proposed approval of the acute ammonia WQS for freshwaters in Washington.

7.1 Background

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), requires federal agencies to consult with NOAA Fisheries on activities that may adversely affect EFH. According to the Magnuson-Stevens Fishery Conservation and Management Act (MSA§3), EFH means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth and maturity. For the purpose of interpreting this definition of EFH: "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish; "substrate" includes sediment, hard bottom , structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, and growth to maturity" covers a species' full life cycle (1976). "Adverse effect" means any impact which reduces quality and/or quantity of EFH, and may include direct (e.g. physical disruption), indirect (e.g. loss of prey), site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (1976).

Pursuant to the MSA, the Pacific Fisheries Management Council (PFMC) has designated EFH for three species of federally-managed Pacific salmon: Chinook (*Oncorhynchus tshawytscha*); coho (O. *kisutch*); and Puget Sound pink salmon (O. *gorbuscha*) (PFMC 2000). Freshwater EFH for Pacific salmon includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable man-made barriers (as identified by PFMC (2000)), and longstanding, naturally-impassable barriers (i.e. natural waterfalls in existence for several hundred years).

The objective of this EFH assessment is to determine if the proposed action may "adversely affect" designated EFH for relevant commercially or federally managed fisheries species within the proposed action area. It also describes conservation measures proposed to avoid, minimize or otherwise offset potential adverse effects to designated EFH resulting from the proposed action.

USEPA reviewed the NMFS information and (www.fisheries.noaa.gov/resource/map/essential-fish-habitat-mapper) to determine if the Action Area for this BE overlaps with EFH. In this case this overlap would be restricted to the EFH species that use freshwater habitats because the ammonia water quality standard for freshwaters in Washington is not relevant to marine waters. The USEPA made the following determinations regarding species in the action area:

- Puget Sound pink salmon. Washington freshwaters are within the distribution of pink salmon. Pink salmon are present and use the Action Area as a migration corridor, spawning habitat, rearing habitat, and smolt out-migration habitat.

- Chinook salmon. Washington freshwaters have been designated as EFH for Chinook salmon. Chinook salmon are present and use the Action Area as a migration corridor, spawning habitat, rearing habitat, and smolt out-migration habitat.
- Coho salmon. Washington freshwaters have been designated as EFH for coho salmon. Coho salmon are present and use the Action Area as a migration corridor, spawning habitat, rearing habitat, and smolt out-migration habitat.

7.2 Description of the Project/Proposed Activity

The activity under consideration for this EFH assessment is identical to the description contained in this Biological Evaluation (BE) for this action, as described in sections 1 and 2 of the BE.

Water quality is an important component of EFH. The potential effects of this action on EFH within the Action Area are the same as those described for fish species of concern in section 5. Effects determinations made for all Salmonid species (including pink salmon, which are not ESA listed) are identical. A summary of the determinations made for salmonid species is found in section 6, and these apply to pink salmon. Based on these determinations, the USEPA has determined the action is **NLAA coho salmon EFH, Chinook salmon EFH, and Puget Sound pink salmon EFH** in this area.

7.3 EFH Conservation Measures and Conclusion

Based on the analysis above, EPA concludes that the agency action is not likely to adversely affect EFH for Puget Sound pink salmon, chinook salmon, and coho salmon.

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NOAA Fisheries. 2016e. Critical habitat Middle Columbia River steelhead. National Oceanic and Atmospheric Administration Fisheries.
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NOAA Fisheries. 2016h. Critical habitat Snake River Basin steelhead. National Oceanic and Atmospheric Admistration Fisheries.
NOAA Fisheries. 2016i. Critical habitat Upper Columbia River spring-run Chinook salmon. National Oceanic and Atmospheric Admistration Fisheries.
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Appendix A. NPDES Permittees with Ammonia Limits

Facility Name	Facility Type	Permit Number
Buckhorn Mountain Mine	IND	WA0052434
Darigold Sunnyside	IND	WA0052078
Port of Sunnyside IWWTF	IND	WA0052426
QUINCY INDUSTRIAL	IND	WA0021067
Seattle Iron & Metals Corp	IND	WA0031968
SOLVAY CHEMICALS INC	IND	WA0991024
SONOCO PRODUCTS COMPANY	IND	WA0000884
Voights Creek Hatchery	IND	WA0039730
Whatcom Cnty Cedarville Landfill	IND	WA0501490
Innovative Repair	IND SW	WAR303580
United Parcel Service - Port of Tacoma	IND SW	WAR305919
ALBION STP	POTW/STP/WWTP	WA0022608
Benton City POTW	POTW/STP/WWTP	WA0051349
Bingen POTW	POTW/STP/WWTP	WA0022373
BUCKLEY STP	POTW/STP/WWTP	WA0023361
Buena POTW	POTW/STP/WWTP	WA0052132
CAMAS STP	POTW/STP/WWTP	WA0020249
CARBONADO STP	POTW/STP/WWTP	WA0020834
CEDAR CREEK CORRECTIONS CENTER STP	POTW/STP/WWTP	WA0037737
CENTRALIA STP	POTW/STP/WWTP	WA0020982
CHENEY WWTP	POTW/STP/WWTP	WA0020842
CHERRYWOOD MOBILE HOME MANOR	POTW/STP/WWTP	WA0037079
CHEWELAH WWTP	POTW/STP/WWTP	WA0023604
CLARKSTON WWTP	POTW/STP/WWTP	WA0021113
COLLEGE PLACE STP	POTW/STP/WWTP	WA0020656
COLVILLE STP	POTW/STP/WWTP	WA0022616
DAVENPORT WWTP	POTW/STP/WWTP	WA0045578
DAYTON STP	POTW/STP/WWTP	WA0020729
Douglas County Sewer District WWTP	POTW/STP/WWTP	WA0020621
EATONVILLE STP	POTW/STP/WWTP	WA0037231
Ellensburg POTW	POTW/STP/WWTP	WA0024341
ENDICOTT STP	POTW/STP/WWTP	WA0023981
ENUMCLAW STP	POTW/STP/WWTP	WA0020575
EVERETT STP	POTW/STP/WWTP	WA0024490
FAIRFIELD WWTP	POTW/STP/WWTP	WA0045489
GARFIELD STP	POTW/STP/WWTP	WA0044822
Goldendale POTW	POTW/STP/WWTP	WA0021121

Facility Name	Facility Type	Permit Number
Grandview POTW	POTW/STP/WWTP	WA0052205
King County Carnation WWTP	POTW/STP/WWTP	WA0032182
Kitsap County Central Kitsap WWTP	POTW/STP/WWTP	WA0030520
Kittitas POTW	POTW/STP/WWTP	WA0021253
Klickitat POTW	POTW/STP/WWTP	WA0023698
LA CENTER STP	POTW/STP/WWTP	WA0023230
LA CONNER STP	POTW/STP/WWTP	WA0022446
LARCH CORRECTION CENTER	POTW/STP/WWTP	WA0038687
LEWIS COUNTY WATER DIST NO 2	POTW/STP/WWTP	WA0024546
LIBERTY LAKE SEWER & WATER DIST	POTW/STP/WWTP	WA0045144
Mabton POTW	POTW/STP/WWTP	WA0020648
MARYSVILLE STP	POTW/STP/WWTP	WA0022497
MCCLEARY STP	POTW/STP/WWTP	WA0024040
METALINE STP	POTW/STP/WWTP	WA0020699
Naches POTW	POTW/STP/WWTP	WA0022586
ODESSA STP	POTW/STP/WWTP	WA0045560
ORTING STP	POTW/STP/WWTP	WA0020303
OTHELLO STP	POTW/STP/WWTP	WA0022357
PACIFIC BEACH STP	POTW/STP/WWTP	WA0037095
PALOUSE STP	POTW/STP/WWTP	WA0044806
PE ELL STP	POTW/STP/WWTP	WA0020192
POMEROY STP	POTW/STP/WWTP	WA0021164
Prosser POTW	POTW/STP/WWTP	WA0020800
PULLMAN WWTP	POTW/STP/WWTP	WA0044652
REARDAN STP	POTW/STP/WWTP	WA0045306
Richland POTW	POTW/STP/WWTP	WA0020419
RIDGEFIELD STP	POTW/STP/WWTP	WA0023272
ROSALIA STP	POTW/STP/WWTP	WA0044687
SALMON CREEK STP	POTW/STP/WWTP	WA0023639
Selah POTW	POTW/STP/WWTP	WA0021032
SOUTH PRAIRIE STP	POTW/STP/WWTP	WA0040479
SPANGLE WWTP	POTW/STP/WWTP	WA0991010
SPOKANE COUNTY REGIONAL WATER RECLAMATION FACILITY (SCRWRF)	POTW/STP/WWTP	WA0093317
SPOKANE RIVERSIDE PARK AWTF AND CSOs	POTW/STP/WWTP	WA0024473
Stevens Pass Sewer District	POTW/STP/WWTP	WA0029521
SUMNER STP	POTW/STP/WWTP	WA0023353
Sunnyside POTW	POTW/STP/WWTP	WA0020991
TEKOA STP	POTW/STP/WWTP	WA0023141

Facility Name	Facility Type	Permit Number
THREE RIVERS REGIONAL WASTEWATER	POTW/STP/WWTP	WA0037788
Vantage POTW	POTW/STP/WWTP	WA0050474
WAITSBURG STP	POTW/STP/WWTP	WA0045551
WASHOUGAL STP	POTW/STP/WWTP	WA0037427
Wenatchee POTW	POTW/STP/WWTP	WA0023949
West Richland POTW	POTW/STP/WWTP	WA0051063
WILBUR STP	POTW/STP/WWTP	WA0044920
WILKESON STP	POTW/STP/WWTP	WA0023281
Zillah POTW	POTW/STP/WWTP	WA0020168
Chehalis Water Reclamation Facility	RW	WA0021105
MEDICAL LAKE WATER RECLAMATION FACILITY	RW	WA0021148
Sequim Water Reclamation Facility	RW	WA0022349
SNOQUALMIE WWTP AND RECLAIM FACILITY	RW	WA0022403
WALLA WALLA WATER RECLAMATION FACILITY	RW	WA0024627
Yelm Water Reclamation Facility	RW	WA0040762

Abbreviations:

IND	Industrial Process Wastewater
IND SW	Industrial Stormwater
POTW/STP/WWTP	Publicly Owned Treatment Works / Sewage Treatment Plant / Wastewater Treatment Plant (Domestic Wastewater)
RW	Reclaimed Water (Domestic Wastewater)

Appendix B. Empirical Acute Toxicity Data, LC50s, LC5, LC50:LC5, and Concentration-response Model Fit Notes for Acceptable and Qualitatively Acceptable Model Fits

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	1.000	Survival	*Margaritifera falcata*	(Wang et al. 2017)	Am-Acute 1	Acceptable (1)	Model: Weibull type 1, 2 para; One observation with large residual relative to others.	7.854	2.804	2.801
	0.8	1.000									
	1.7	0.950									
	3.5	0.910									
	7.3	0.640									
	16	0.000									
TAN-mg/L	0	1.000	Survival	*Actinonaias ligamentina*	Wang et al. 2007b	Am-Acute 2	Acceptable (1)	Model: Weibull type 1, 2 para; Residuals indicate possible bias and one overly influential observation. These are most likely due to the steep slope of fitted curve.	7.278	4.319	1.685
	0.5	1.000									
	1	1.000									
	2	1.000									
	4	0.963									
	8	0.330									
	16	0.000									
TAN-mg/L	0	0.997	Survival	*Actinonaias ligamentina*	Wang et al. 2007b	Am-Acute 3	Acceptable (1)	Model: Weibull type 1, 3 para; Model performs well on all metrics.	9.649	3.965	2.433
	1	0.993									
	2	0.993									
	4	0.927									
	8	0.690									
	16	0.043									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	0.997	Survival	*Actinonaias ligamentina*	Wang et al. 2007b	Am-Acute 4	Acceptable (1)	Model: Weibull type 2, 4 para; Model performs well on all metrics.	6.727	2.373	2.835
	0.5	1.000									
	1	1.000									
	2	0.973									
	4	0.703									
	8	0.310									
	16	0.017									
TAN-mg/L	0	0.993	Survival	*Actinonaias ligamentina*	Wang et al. 2007b	Am-Acute 5	Qualitatively Acceptable (2)	Model: Brain-Cousens, 4 para; Poor goodness of fit p-value and one overly influential observation, but otherwise as adequate model.	9.643	7.798	1.237
	1	0.870									
	2	0.997									
	4	0.990									
	8	0.863									
	16	0.007									
TAN-mg/L	0	0.960	Survival	*Actinonaias heterodon*	Wang et al. 2007b	Am-Acute 6	Acceptable (1)	Model: Weibull type 2, 3 para; One overly influential observation.	21.589	6.941	3.111
	1	0.910									
	2	0.890									
	4	0.897									
	8	0.843									
	16	0.583									
TAN-mg/L	0.1	0.920	Survival	*Amblema plecata*	Wang et al. 2017	Am-Acute 7	Qualitatively Acceptable (2)	Model: Weibull type 2, 3 para; Wide confidence band on fitted line and overly influential observation.	1.580	1.036	1.524
	0.6	0.920									
	2	0.240									
	4.1	0.028									
	8	0.000									
	15.3	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	0.950	Survival	*Epioblasma capsaeformis*	(Wang et al. 2007b)	Am-Acute 8	Acceptable (1)	Model: Weibull type 1, 3 para; Model generally performs well.	6.094	3.342	1.824
	1	0.950									
	2	0.950									
	4	0.850									
	8	0.100									
	16	0.000									
TAN-mg/L	0	0.933	Survival	*Epioblasma capsaeformis*	(Wang et al. 2007b)	Am-Acute 9	Acceptable (1)	Model: Weibull type 1, 3 para; Poor goodness of fit p-value, but otherwise model performs well.	6.045	1.768	3.420
	0.5	1.000									
	1	0.843									
	2	0.860									
	4	0.767									
	8	0.233									
	16	0.007									
TAN-mg/L	0	0.937	Survival	*Epioblasma capsaeformis*	(Wang et al. 2007b)	Am-Acute 10	Accepatble (1)	Model: Weibull type 1, 3 para; Poor goodness of fit p-value, but otherwise model performs well.	3.716	0.239	15.581
	1	0.833									
	2	0.683									
	4	0.467									
	8	0.027									
	16	0.147									
TAN-mg/L	0.16	1.000	Survival	*Lampsilis abrupta*	(Wang et al. 2007a)	Am-Acute 11	Acceptable (1)	Model: Weibull type 1, 2 para; One overly influential observation, but otherwise model performs well.	2.484	0.860	2.889
	0.43	0.973									
	0.78	0.925									
	1.66	0.875									
	3.47	0.175									
	7.42	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	1.000	Survival	*Lampsilis fasciola*	(Mummert et al. 2003)	Am-Acute 12	Unacceptable (3)	Model: Weibull type 1, 3 para; One parameter not significant. Poor goodness of fit p-value. Wide confidence band on fitted model. Poor QQ line.	0.242	0.184	1.314
	0	1.000									
	0	1.000									
	0	0.800									
	0.053	1.000									
	0.053	0.900									
	0.053	0.900									
	0.053	0.900									
	0.098	1.000									
	0.098	1.000									
	0.098	0.900									
	0.098	0.700									
	0.21	0.900									
	0.21	0.800									
	0.21	0.800									
	0.21	0.600									
	0.33	0.000									
	0.33	0.000									
	0.33	0.000									
	0.33	0.000									
	0.55	0.000									
	0.55	0.000									
	0.55	0.000									
	0.55	0.000									
TAN-mg/L	0	0.950	Survival	*Lampsilis fasciola*	(Wang et al. 2007b)	Am-Acute 13	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; Poor goodness of fit p-value and the lower bound on the EC5 estimate just dips below zero.	8.322	1.867	4.457
	1	0.900									
	2	1.000									
	4	0.500									
	8	0.750									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	16	0.050									
TAN-mg/L	0	0.970	Survival	*Lampsilis fasciola*	(Wang et al. 2007b)	Am-Acute 14	Acceptable (1)	Model: Weibull type 1, 3 para; Poor goodness of fit p-value, but otherwise model performs well.	9.270	3.314	2.797
	0.5	0.977									
	1	0.987									
	2	0.973									
	4	0.857									
	8	0.653									
	16	0.053									
TAN-mg/L	0	0.987	Survival	*Lampsilis fasciola*		Am-Acute 15	Acceptable (1)	Model: Weibull type 1, 3 para; Model performs well on all metrics.	6.747	1.552	4.346
	1	0.970									
	2	0.907									
	4	0.770									
	8	0.360									
	16	0.047									
TAN-mg/L	0	1.000	Survival	*Lampsilis rafinesqueana*		Am-Acute 16	Qualitatively Acceptable (2)	Model: Weibull type 2, 3 para; One parameter is insignificant. Wide confidence band on fitted model, most likely due to a steep response curve. Poor residuals.	9.441	8.631	1.094
	1	0.950									
	2	0.950									
	4	0.950									
	8	1.000									
	16	0.000									
TAN-mg/L	0	0.950	Survival	*Lampsilis rafinesqueana*		Am-Acute 17	Acceptable (1)	Model: Weibull type 2, 3 para; QQ plot is a bit off and one overly influential observation.	10.688	5.081	2.104
	1	1.000									
	2	1.000									
	4	1.000									
	8	0.650									
	16	0.300									
TAN-mg/L	0.0	0.990	Survival	*Lampsilis rafinesqueiana*		Am-Acute 18	Acceptable (1)	Model: Weibull type 2, 3 para; One overly influential observation,	8.198	6.636	1.235
	0.5	0.993									
	1.0	0.993									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	2.0	0.977						but otherwise model performs well.			
	4.0	0.987									
	8.0	0.553									
	16.0	0.007									
TAN-mg/L	0.1	0.950	Survival	*Lampsilis siliquoidea*	(Miao et al. 2010)	Am-Acute 19	Acceptable (1)	Model: Weibull type 1, 2 para; Poor goodness of fit p-value and observations off the QQ line.	7.773	1.238	6.277
	0.8	0.900									
	1.8	0.900									
	3.7	1.000									
	7.1	0.650									
	18.5	0.000									
TAN-mg/L	0.16	0.950	Survival	*Lampsilis siliquoidea*	(Wang et al. 2007a)	Am-Acute 20	Acceptable (1)	Model: Weibull type 1, 2 para; Poor goodness of fit p-value and observations off the QQ line.	4.079	1.198	3.406
	0.43	1.000									
	0.78	1.000									
	1.66	0.950									
	3.47	0.659									
	7.42	0.050									
TAN-mg/L	0.0	0.930	Survival	*Lampsilis siliquoidea*	(Wang et al. 2008)	Am-Acute 21	Acceptable (1)	Model: Weibull type 2, 3 para; QQ plot is a bit off and one overly influential observation.	9.869	6.345	1.556
	1.1	0.930									
	2.0	0.900									
	3.8	0.920									
	7.7	0.730									
	19.0	0.070									
TAN-mg/L	0.0	1.000	Survival	*Lampsilis siliquoidea*		Am-Acute 22	Acceptable (1)	Model: Weibull type 2, 2 para; QQ plot is a bit off and one overly influential observation.	4.582	3.423	1.338
	1.0	1.000									
	1.9	1.000									
	3.8	0.830									
	8.6	0.030									
	19.0	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0.0	1.000	Survival	*Lampsilis siliquoidea*		Am-Acute 23	Acceptable (1)	Model: Weibull type 1, 2 para; QQ plot is a bit off and one overly influential observation.	3.415	1.171	2.916
	1.1	0.900									
	1.9	0.930									
	3.9	0.370									
	8.5	0.000									
	19.0	0.000									
TAN-mg/L	0.0	1.000	Survival	*Lampsilis siliquoidea*		Am-Acute 24	Acceptable (1)	Model: Weibull type 1, 2 para; QQ plot is a bit off and one overly influential observation.	1.010	0.412	2.449
	0.3	1.000									
	0.5	0.830									
	1.0	0.600									
	1.9	0.000									
	4.4	0.000									
TAN-mg/L	0.0	1.000	Survival	*Lampsilis siliquoidea*		Am-Acute 25	Unacceptable (3)	Model: Weibull type 1, 2 para; No good model can be fit due to the lack of varied response values. This data set suffers from a lack of observations falling between zero and one.	113.416	101.819	1.114
	7.1	1.000									
	15.0	1.000									
	30.0	1.000									
	60.0	1.000									
	130.0	0.000									
TAN-mg/L	0	0.970	Survival	*Lampsilis siliquoidea*		Am-Acute 26	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; Wide confidence band around fitted model. QQ plot is off. Overly influential observation. This data set suffers from a lack of responses falling between zero and one, however a model was able to be fit.	12.720	8.460	1.504
	1	1.000									
	2	1.000									
	4.1	0.900									
	9	0.900									
	19	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0.0	0.990	Survival	*Lampsilis siliquoidea*	(Wang et al. 2007b)	Am-Acute 27	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; One overly influential observation. This data set also suffers from lack of responses falling between zero and one. Statistical metrics are good, however any inferences made from this set should be examined closely given this lack of partial effects.	12.695	8.359	1.519
	0.5	1.000									
	1.0	0.997									
	2.0	0.993									
	4.0	1.000									
	8.0	0.957									
	16.0	0.053									
TAN-mg/L	0	0.993	Survival	*Lampsilis siliquoidea*		Am-Acute 28	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; One overly influential observation. This data set also suffers from lack of responses falling between zero and one. Statistical metrics are good, however any inferences made from this set should be examined closely given this lack of partial effects.	15.490	7.981	1.941
	0.5	0.993									
	1	0.993									
	2	0.977									
	4	0.987									
	8	0.940									
	16	0.450									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0.0	0.993	Survival	*Lampsilis siliquoidea*		Am-Acute 29	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; One overly influential observation. This data set also suffers from lack of responses falling between zero and one. Statistical metrics are good, however any inferences made from this set should be examined closely given this lack of partial effects.	14.958	10.333	1.448
	1.0	0.997									
	2.0	0.997									
	4.0	0.993									
	8.0	0.987									
	16.0	0.327									
TAN-mg/L	0	1.000	Survival	*Lampsilis siliquoidea*		Am-Acute 30	Acceptable (1)	Model: Weibull type 1, 2 para; Poor goodness of fit p-value, but otherwise model performs well.	7.791	2.168	3.594
	1	0.973									
	2	0.963									
	4	0.880									
	8	0.447									
	16	0.053									
TAN-mg/L	0.0	1.000	Survival	*Lampsilis siliquoidea*		Am-Acute 31	Acceptable (1)	Model: Weibull type 1, 3 para; One overly influential observation, but otherwise model performs well.	10.530	5.473	1.924
	0.5	1.000									
	1.0	0.997									
	2.0	1.000									
	4.0	1.000									
	8.0	0.763									
	16.0	0.030									
TAN-mg/L	0.1	0.930	Survival	*Megalonaias nervosa*	Wang et al. 2017	Am-Acute 32	Acceptable (1)	Model: Weibull type 1, 3 para; Model performs well on all metrics.	5.297	0.970	5.461
	1.1	0.850									
	2.1	0.680									
	4.4	0.630									
	8.8	0.200									
	19.0	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0.0	1.000	Survival	*Potamilus ohiensis*	(Wang et al. 2007b)	Am-Acute 33	Qualitatively Acceptable (2)	Model: Weibull type 1, 2 para; One overly influential observation. This data set also suffers from lack of responses falling between zero and one. Statistical metrics are good, however any inferences made from this set should be examined closely given this lack of partial effects.	16.893	9.251	1.826
	0.5	1.000									
	1.0	1.000									
	2.0	1.000									
	4.0	0.997									
	8.0	0.977									
	16.0	0.577									
TAN-mg/L	0	0.950	Survival	*Pygandon grandis*	(Scheller 1997)	Am-Acute 34	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; EC estimates all have negative lower bounds.	14.015	0.041	341.973
	9.6	0.650									
	29.8	0.400									
	99	0.000									
	311.1	0.050									
	1006.7	0.050									
TAN-mg/L	0	1.000	Survival	*Pygandon grandis*		Am-Acute 35	Qualitatively Acceptable (2)	Model: Weibull type 1, 2 para; Most EC estimates have negative lower bounds.	23.267	0.908	25.612
	10	0.650									
	29.2	0.500									
	102.5	0.100									
	294.7	0.000									
	1030	0.000									
TAN-mg/L	0.52	1.000	Survival	*Utterbackia imbecillis*	Wade 1992	Am-Acute 36	Qualitatively Acceptable (2)	Model: Log Logistic type 1, 2 para; Poor goodness of fit p-value. The author reports a proportion survived value of 1.06 (106%) ...not sure how this value is determined.	18.966	7.178	2.642
	0.52	1.000									
	0.52	1.000									
	2.54	1.000									
	2.54	0.933									
	2.54	1.000									
	4.7	0.933									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	4.7	1.067									
	4.7	0.933									
	9.04	1.000									
	9.04	0.933									
	9.04	1.000									
	17.59	0.533									
	17.59	0.467									
	17.59	0.533									
TAN-mg/L	0	0.900	Survival	*Utterbackia imbecillis*	Wang et al. 2017	Am-Acute 37	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; Poor goodness of fit p-value. Overly influential observation.	2.216	1.265	1.753
	0.9	0.580									
	1.8	0.600									
	3.6	0.000									
	8	0.000									
	16	0.000									
TAN-mg/L	0	0.997	Survival	*Venustaconcha ellipsiformis*	Wang et al. 2007b	Am-Acute 38	Acceptable (1)	Model: Weibull type 2, 3 para; Model performs well on all metrics.	4.740	2.215	2.139
	0.5	0.993									
	1	0.997									
	2	0.977									
	4	0.583									
	8	0.250									
	16	0.060									
TAN-mg/L	0	1.000	Survival	*Villosa iris*	Wang et al. 2007b	Am-Acute 39	Acceptable (1)	Model: Weibull type 2, 3 para; One overly influential observation, but otherwise model performs well.	3.056	2.090	1.462
	1	0.900									
	2	0.950									
	4	0.150									
	8	0.050									
	16	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	1.000	Survival	*Villosa iris*	Wang et al. 2007b	Am-Acute 40	Acceptable (1)	Model: Weibull type 1, 2 para; Poor goodness of fit p-value, but otherwise model performs well.	11.537	2.762	4.176
	1	0.950									
	2	1.050									
	4	0.900									
	8	0.650									
	16	0.300									
TAN-mg/L	0	1.000	Survival	*Villosa iris*	Scheller 1997	Am-Acute 41	Acceptable (1)	Model: Log Logistic type 1, 2 para; One overly influential observation, but otherwise model performs well.	15.948	6.504	2.452
	1.22	1.000									
	3.58	1.000									
	6.1	0.950									
	9.29	0.850									
	18.18	0.400									
TAN-mg/L	0	0.850	Survival	*Villosa iris*	Wang et al. 2007b	Am-Acute 42	Acceptable (1)	Model: Weibull type 1, 3 para; One overly influential observation, but otherwise model performs well.	6.759	3.220	2.099
	1	0.800									
	2	0.950									
	4.0	0.750									
	8	0.250									
	16	0.000									
TAN-mg/L	0	0.900	Survival	*Villosa iris*	Mummert et al. 2003	Am-Acute 43	Acceptable (1)	Model: Weibull type 1, 4 para; Poor goodness of fit p-value, but otherwise model performs well.	0.103	0.033	3.094
	0	0.900									
	0	0.900									
	0	0.900									
	0.054	0.700									
	0.054	0.700									
	0.054	0.700									
	0.054	0.600									
	0.11	0.800									
	0.11	0.600									
	0.11	0.300									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	0.11	0.300									
	0.19	0.100									
	0.19	0.100									
	0.19	0.000									
	0.19	0.000									
	0.34	0.100									
	0.34	0.100									
	0.34	0.000									
	0.34	0.000									
	0.54	0.100									
	0.54	0.000									
	0.54	0.000									
	0.54	0.000									
TAN-mg/L	0	0.950	Survival	*Villosa iris*	Scheller 1997	Am-Acute 44	Acceptable (1)	Model: Weibull type 2, 3 para; Model performs well.	7.730	2.508	3.082
	0.63	1.000									
	1.25	0.950									
	2.5	1.000									
	5	0.500									
	10	0.500									
TAN-mg/L	0	0.974	Survival	*Villosa iris*	Scheller 1997	Am-Acute 45	Unacceptable (3)	Model: Weibull type 2, 3 para; Poor goodness of fit p-value. Overly influential observations. Poor QQ line. Data lacks partial effects.	3.592	2.540	1.415
	3.25	0.648									
	6.4	0.018									
	14	0.006									
	28	0.007									
	55	0.000									
	95	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	0.997	Survival	*Villosa iris*	Wang et al. 2007b	Am-Acute 46	Unacceptable (3)	Model: Weibull type 1, 3 para; Poor goodness of fit p-value. Overly influential observations. Poor QQ line. Data lacks partial effects.	12.348	6.523	1.893
	0.5	1.000									
	1	0.990									
	2	0.990									
	4	0.930									
	8	0.913									
	16	0.127									
TAN-mg/L	0.03	1.000	Survival	*Ceriodaphnia dubia*	Anderson and Buckley 1998	Am-Acute 47	Acceptable (1)	Model: Weibull type 1, 2 para; Model performs well on all metrics.	22.372	8.944	2.501
	9.31	0.920									
	16.91	0.770									
	27.42	0.290									
	35.48	0.070									
	43.55	0.010									
TAN-mg/L	0	1.000	Survival	*Ceriodaphnia dubia*	Sarda 1994	Am-Acute 48	Acceptable (1)	Model: Weibull type 2, 3 para; Poor goodness of fit p-value and possible lack of partial effects, but otherwise model performs well.	26.867	19.687	1.365
	0	0.900									
	0	1.000									
	13.5	1.000									
	13.5	1.000									
	13.5	1.000									
	20.4	1.000									
	20.4	0.900									
	20.4	1.000									
	28	0.300									
	28	0.200									
	28	0.300									
	40	0.200									
	40	0.100									
	40	0.000									
	52	0.200									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	52	0.000									
	52	0.100									
TAN-mg/L	0	1.000	Survival	*Ceriodaphnia dubia*	Sarda 1994	Am-Acute 49	Acceptable (1)	Model: Weibull type 2, 2 para; Model performs well on all metrics.	26.563	19.439	1.366
	0	1.000									
	0	1.000									
	15.2	1.000									
	15.2	1.000									
	15.2	1.000									
	25.3	0.600									
	25.3	0.600									
	25.3	0.500									
	29.6	0.500									
	29.6	0.400									
	29.6	0.200									
	39	0.200									
	39	0.100									
	39	0.000									
	50.2	0.100									
	50.2	0.000									
	50.2	0.000									
TAN-mg/L	0.04	0.900	Survival	*Orconectes nais*	Evans 1979	Am-Acute 50	Qualitatively Acceptable (2)	Model: Weibull type 1, 2 para; Most lower bounds on EC estimates are negative and somewhat wide confidence band on fitted model.	3.249	0.011	296.108
	0.04	0.900									
	2.035	0.600									
	2.035	0.600									
	3.16	0.500									
	3.16	0.500									
	3.3	0.700									
	3.3	0.500									
	4.1	0.300									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	4.1	0.400									
TAN-mg/L	0.11	0.800	Survival	*Stenelmis sexlineata*	(Hazel et al. 1979) Hazel et al. 1979	Am-Acute 51	Qualitatively Acceptable (2)	Model: Weibull type 2, 3 para; Possible lack of partial effects.	29.489	24.273	1.215
	0.11	0.800									
	18.4	0.800									
	18.4	0.800									
	22	0.800									
	22	0.800									
	25.5	0.700									
	25.5	0.700									
	32	0.300									
	32	0.200									
TAN-mg/L	0.4	1.000	Survival	*Oncorhynchus mykiss*	Wicks and Randall 2002	Am-Acute 52	Unacceptable (3)	Model: Weibull type 1, 2 para; Possible lack of partial effects. One model parameter is not significant. EC5 lower bound is negative. Wide confidence band on fitted model.	183.274	137.576	1.332
	0.4	1.000									
	189	0.400									
	189	0.400									
	250	0.000									
	250	0.000									
	272	0.000									
	272	0.000									
TAN-mg/L	0	1.000	Survival	*Campostoma anomalum*	(Swigert and Spacie 1983)	Am-Acute 55	Acceptable (1)	Model: Weibull type 1, 2 para; One overly influential observation, but otherwise model performs well.	1.445	0.991	1.458
	0.45	1.000									
	0.56	1.000									
	0.83	0.920									
	1.36	0.770									
	1.83	0.000									
TAN-mg/L	0.01	1.000	Survival	*Cyprinella lutrensis*	Hazel et al. 1979	Am-Acute 56	Acceptable (1)	Model: Weibull type 1, 3 para; Model performs well on all metrics.	22.205	14.656	1.515
	0.01	1.000									
	15	1.000									
	15	0.800									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	20	0.700									
	20	0.800									
	25	0.300									
	25	0.200									
	30	0.000									
	30	0.000									
TAN-mg/L	0.14	1.000	Survival	*Cyprinella lutrensis*	Hazel et al. 1979	Am-Acute 57	Acceptable (1)	Model: Log Logistic type 1, 2 para; Model performs well on all metrics.	7.074	5.157	1.372
	0.15	1.000									
	5	0.900									
	5	1.000									
	6	0.900									
	6	0.900									
	7	0.400									
	7	0.400									
	8	0.300									
	8	0.300									
TAN-mg/L	0	1.000	Survival	*Cyprinella lutrensis*	Swigert and Spacie 1983	Am-Acute 58	Unacceptable (3)	Model: Log Logistic type 1, 2 para; Possible lack of partial effects. One model parameter is not significant. Overly influential observation. Wide confidence band on fitted model.	1.093	1.047	1.043
	0.88	1.000									
	0.89	1.000									
	1.08	0.692									
	1.29	0.000									
TAN-mg/L	0	0.969	Survival	*Cyprinus carpio*	Hasan and MacIntosh 1986	Am-Acute 59	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; Lack of partial effects and one overly influential observation.	1.788	1.249	1.432
	0.19	1.000									
	0.23	1.000									
	0.43	0.969									
	0.69	0.937									
	1.39	0.875									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	2.54	0.000									
	4.8	0.000									
TAN-mg/L	0	1.000	Survival	*Cyprinus carpio*	Hasan and MacIntosh 1986	Am-Acute 60	Acceptable (1)	Model: Weibull type 1, 2 para; Two overly influential observations, but otherwise model performs well.	1.893	1.376	1.376
	0.5	1.000									
	0.84	1.000									
	1	1.000									
	1.56	0.844									
	2.13	0.187									
	2.42	0.000									
	2.62	0.000									
TAN-mg/L	0	1.000	Survival	*Hybognathus amarus*	(Buhl 2002) Buhl 2002	Am-Acute 61	Acceptable (1)	Model: Weibull type 1, 2 para; Confidence band on fitted model is a bit wide and one overly influential observation, but otherwise model performs well.	17.151	8.476	2.023
	2.7	1.000									
	4.44	1.000									
	7.38	0.900									
	13	0.900									
	20.9	0.200									
	35.2	0.000									
	58.2	0.000									
	96.7	0.000									
	168	0.000									
TAN-mg/L	0	1.000	Survival	*Notemigonus crysoleucas*	Swigert and Spacie 1983	Am-Acute 62	Acceptable (1)	Model: Weibull type 1, 2 para; Model performs well on all metrics.	0.594	0.260	2.282
	0	1.000									
	0.07	1.000									
	0.07	1.000									
	0.14	1.000									
	0.15	1.000									
	0.3	0.800									
	0.31	0.900									
	0.58	0.500									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	0.6	0.700									
	1.02	0.000									
	1.08	0.000									
TAN-mg/L	0	1.000	Survival	*Pimephales promelas*	Swigert and Spacie 1983	Am-Acute 63	Qualitatively Acceptable (2)	Model: Weibull type 1, 2 para; One model parameter no significant. Confidence band on fitted model is wide in some portion. Bad QQ line. Overly influential observation.	1.530	1.442	1.061
	0	1.000									
	0.58	1.000									
	0.61	1.000									
	0.85	1.000									
	0.85	1.000									
	1.14	1.000									
	1.1	1.000									
	1.54	0.400									
	1.56	0.200									
	1.83	0.000									
	1.91	0.000									
TAN-mg/L	0	1.000	Survival	*Pimephales promelas*	Swigert and Spacie 1983	Am-Acute 64	Acceptable (1)	Model: Log Logistic type 1, 3 para; Poor goodness of fit p-value. Two overly influential observations.	1.558	1.283	1.215
	0	0.900									
	0.3	1.000									
	0.34	1.000									
	0.71	0.900									
	0.75	1.000									
	0.99	1.000									
	1.03	1.000									
	1.56	0.300									
	1.59	0.600									
	2.22	0.000									
	2.41	0.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	0	1.000	Survival	*Catostomus commersonii*	(Reinbold and Pescitelli 1982b)	Am-Acute 65	Acceptable (1)	Model: Log Logistic type 1, 2 para; Model performs well on all metrics.	1.097	0.778	1.411
	0	1.000									
	0.59	1.000									
	0.55	1.000									
	0.77	1.000									
	0.66	1.000									
	0.86	0.900									
	0.83	0.800									
	1.16	0.400									
	1.34	0.200									
	1.81	0.000									
	1.86	0.000									
TAN-mg/L	0	1.000	Survival	*Catostomus commersonii*	Swigert and Spacie 1983	Am-Acute 66	Qualitatively Acceptable (2)	Model: Weibull type 1, 2 para; One model parameter not significant. Wide confidence band on fitted model. One overly influential observation.	0.760	0.683	1.113
	0	1.000									
	0.07	1.000									
	0.11	1.000									
	0.25	1.000									
	0.25	1.000									
	0.44	1.000									
	0.46	1.000									
	0.8	0.090									
	0.79	0.170									
	1.28	0.000									
	1.55	0.000									
TAN-mg/L	0	1.000	Survival	*Ictalurus punctatus*	(Reinbold and Pescitelli 1982a)	Am-Acute 67	Acceptable (1)	Model: Log Logistic type 1, 2 para; Two overly influential observations, but otherwise model performs well.	1.422	1.104	1.288
	0	1.000									
	0.56	1.000									
	0.6	1.000									
	0.87	1.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	0.93	1.000									
	1.46	0.700									
	1.43	0.200									
	2.66	0.000									
	2.6	0.000									
	4.5	0.000									
	4.85	0.000									
TAN-mg/L	0	1.000	Survival	*Ictalurus punctatus*	Swigert and Spacie 1983	Am-Acute 69	Unacceptable (3)	Model: Weibull type 2, 2 para; One model parameter not significant. Lack of partial effects. Wide confidence band on fitted model.	1.042	0.991	1.051
	0	1.000									
	0.66	1.000									
	0.71	1.000									
	1	0.900									
	1	0.900									
	1.53	0.000									
	1.58	0.000									
	2.13	0.000									
	2.31	0.000									
TAN-mg/L	0.3	1.000	Survival	*Lepomis macrochirus*	Hazel et al. 1979	Am-Acute 71	Acceptable (1)	Model: Weibull type 2, 2 para; Model performs well on all metrics.	6.647	6.037	1.101
	0.3	1.000									
	5.2	1.000									
	5.2	1.000									
	6.1	1.000									
	6.1	0.900									
	6.4	0.600									
	6.4	0.700									
	7.4	0.100									
	7.4	0.200									

<table>
<tr><th>Units</th><th>Test Conc.</th><th>Resp.</th><th>End-point</th><th>Species</th><th>Citation</th><th>C-R Curve Label</th><th>Accept-ability</th><th>Curve Notes</th><th>LC50</th><th>LC5</th><th>LC50: LC5 Ratio</th></tr>
<tr><td rowspan="6">TAN-mg/L</td><td>0</td><td>1.000</td><td rowspan="6">Survival</td><td rowspan="6">Lepomis macrochirus</td><td rowspan="6">(Smith et al. 1984)</td><td rowspan="6">Am-Acute 72</td><td rowspan="6">Unacceptable (3)</td><td rowspan="6">Model: Weibull type 2, 3 para; Lack of partial effects. One model parameter not significant. Wide confidence band on fitted model.</td><td rowspan="6">0.835</td><td rowspan="6">0.766</td><td rowspan="6">1.091</td></tr>
<tr><td>0.08</td><td>0.975</td></tr>
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<tr><td>0.708</td><td>0.975</td></tr>
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<tr><td>0</td><td>1.000</td></tr>
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<tr><td>1.32</td><td>0.360</td></tr>
<tr><td>1.34</td><td>0.430</td></tr>
<tr><td>1.53</td><td>0.000</td></tr>
<tr><td>1.73</td><td>0.000</td></tr>
<tr><td rowspan="11">TAN-mg/L</td><td>0</td><td>1.000</td><td rowspan="11">Survival</td><td rowspan="11">Lepomis macrochirus</td><td rowspan="11">Swigert and Spacie 1983</td><td rowspan="11">Am-Acute 74</td><td rowspan="11">Acceptable (1)</td><td rowspan="11">Model: Weibull type 2, 3 para; Poor goodness of fit p-value. Overly influential observation due to possible lack of partial effects.</td><td rowspan="11">1.366</td><td rowspan="11">1.213</td><td rowspan="11">1.127</td></tr>
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<tr><td>1.39</td><td>0.700</td></tr>
<tr><td>1.32</td><td>0.400</td></tr>
<tr><td>1.79</td><td>0.000</td></tr>
</table>

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	1.84	0.000									
TAN-mg/L	0	1.000	Survival	*Lepomis macrochirus*	Swigert and Spacie 1983	Am-Acute 75	Acceptable (1)	Model: Weibull type 2, 2 para; One overly influential observation, but otherwise model performs well.	1.377	1.120	1.230
	0.84	1.000									
	0.88	1.000									
	1.22	0.800									
	1.88	0.100									
	2.29	0.000									
TAN-mg/L	0.05	1.000	Survival	*Etheostoma spectabile*	Hazel et al. 1979	Am-Acute 76	Acceptable (1)	Model: Weibull type 2, 2 para; Model performs well on all metrics.	34.747	20.131	1.726
	0.05	1.000									
	12.6	1.000									
	12.6	1.000									
	20.4	0.900									
	20.4	1.000									
	35.5	0.300									
	35.5	0.400									
	37.7	0.500									
	37.7	0.600									
TAN-mg/L	0.04	1.000	Survival	*Etheostoma spectabile*	Hazel et al. 1979	Am-Acute 77	Acceptable (1)	Model: Log Logistic type 1, 3 para (LL.3u); Poor QQ line, but otherwise model performs well.	7.109	5.796	1.226
	0.04	1.000									
	4.6	1.000									
	4.6	1.000									
	6.2	0.800									
	6.2	1.000									
	8.7	0.200									
	8.7	0.300									
	10.9	0.200									
	10.9	0.200									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
TAN-mg/L	104.6944232	1.000	Survival	*Oreochromis mossambicus*	(Rani et al. 1998)	Am-Acute 78	Acceptable (1)	Model: Log Logistic type 1, 2 para; Confidence band on fitted model is wide, but otherwise model performs well.	118.194	107.185	1.103
	111.2378246	0.800									
	117.781226	0.500									
	124.3246275	0.300									
	130.8680289	0.000									
	137.4114304	0.000									
	143.9548318	0.000									
	150.4982333	0.000									
	157.0416347	0.000									
TAN-mg/L	0.3	1.000	Survival	*Pseudacris regilla*	Schuytema and Nebecker 1998	Am-Acute 79	Unacceptable (3)	Model: Log Logistic type 1, 2 para; Model does not perform well.	46.918	39.463	1.189
	3.3	1.000									
	6.9	1.000									
	13.3	1.000									
	25.1	1.000									
	50.9	0.200									
	101.2	0.000									
TAN-mg/L	0.2	0.967	Survival	*Pseudacris regilla*	Schuytema and Nebecker 1998	Am-Acute 80	Acceptable (1)	Model: Weibull type 1, 3 para; Model performs well on all metrics.	64.433	29.453	2.188
	2.8	1.000									
	7.3	1.000									
	12.8	1.000									
	24.9	0.933									
	49.7	0.767									
	102.9	0.033									
TAN-mg/L	0.04	1.000	Survival	*Pseudacris regilla*	Schuytema and Nebecker 1998	Am-Acute 81	Unacceptable (3)	Model: Log Logistic type 1, 2 para; Model does not perform well.	93.651	72.777	1.287
	2.6	1.000									
	6.1	1.000									
	11.7	1.000									
	23.1	1.000									
	45.4	1.000									

Units	Test Conc.	Resp.	End-point	Species	Citation	C-R Curve Label	Accept-ability	Curve Notes	LC50	LC5	LC50: LC5 Ratio
	91.5	0.567									
TAN-mg/L	0.3	0.960	Survival	*Xenopus laevis*	Schuytema and Nebecker 1998	Am-Acute 82	Qualitatively Acceptable (2)	Model: Log Logistic type 1, 2 para; Poor goodness of fit p-value and overly influential observations. This model ranked higher in AIC than others, but other models did not perform well.	31.370	12.600	2.490
	3.3	1.000									
	6.9	0.987									
	13.3	0.987									
	25.1	0.867									
	50.9	0.000									
	101.2	0.000									
TAN-mg/L	0.04	1.000	Survival	*Xenopus laevis*	Schuytema and Nebecker 1998	Am-Acute 83	Qualitatively Acceptable (2)	Model: Weibull type 1, 3 para; Lack of partial effects. Wide confidence band on fitted model and EC estimates. Overly influential observation.	64.550	45.578	1.416
	2.6	0.907									
	6.1	0.933									
	11.7	0.933									
	23.1	0.907									
	45.4	0.893									
	91.5	0.000									

Appendix C. Method for Fitting and Evaluating Concentration-Response Data

1. Fitting Concentration Response Data in R

Raw concentration-response data (expressed as log[treatment concentration] paired organismal responses) were obtained from quantitatively-acceptable toxicity studies that reported raw data. In many scenarios, toxicity studies reported treatment-level mean concentrations and mean organismal responses; however, individual-replicate data were also available in many scenarios. When fitting C-R curves, replicate-level data were preferred over treatment-level data, if both types of data were available. Within R, the drc package was employed to fit 22 mathematical models to each set of raw C-R data.

a. Fitting Acute Mortality Data

i. Dichotomous Data

Dichotomous data are binary in nature (e.g. live/dead or 0/1) and are typical of survival experiments. They are usually represented as a proportion survived.

b. Fitting Chronic Growth, Reproduction, and Survival Data

i. Continuous Data

Continuous data take on any value along the real number line (e.g. biomass).

ii. Count Data

Count data take on only integer values (e.g. number of eggs hatched).

iii. Dichotomous Data

Dichotomous data are binary in nature (e.g. live/dead or 0/1) and are typical of survival experiments. They are usually represented as a proportion survived.

2. Determining Most Robust Model Fit for Each C-R curve

The R drc package was used to fit 22 different models to each individual C-R dataset. A single model was then selected from the 22 models to serve as the representative C-R model. The selected model represented the most statistically-robust model available. To determine the most-statistically-robust model for a C-R dataset, all individual model fits were assessed on a suite of statistical metrics.

a. Selecting Candidate Models

Initially, models were ranked according to the Akaike information criteria (AIC). The AIC provides a measure of how close a model's fitted values tend to be to the true expected values, as summarized by a certain expected distance between the two. That is, the model with the lowest AIC is generally the optimal model because it is the model fit that tends to have its fitted values closest to the true outcome probabilities. In some instances, however, the model with the lowest AIC may possesses a questionable characteristic that suggests the model with the lowest AIC may not be the most appropriate. Rather than selecting a model based solely on the lowest AIC, the AIC ranking step was first used to identify several candidate models that were more closely examined before selecting a model fit for each C-R dataset.

b. Assessment of Candidate Models to Determine the Most Appropriate Model

Candidate models (i.e., models with low AIC scores relative to other models produced for a particular C-R dataset) were further evaluated based on additional statistical metrics to determine a single, statistically robust curve for each quantitatively-acceptable toxicity tests. These additional statistical metrics were evaluated relative to the other candidate curve fits produced for each C-R dataset. These additional statistical metrics include:

i. Comparison of residual standard errors

As with AIC, smaller values were desirable. Residual standard errors were judged relative to other models.

ii. Width of confidence intervals for EC estimates

Confidence intervals were assessed on standard error relative to estimate and confirming that the intervals are non-negative. Judged in absolute and relative to other models.

iii. Width of confidence bands around the fitted model

General visual inspection of the confidence bands for the fitted model. Wide bands in the area of interest were undesirable. Judged in absolute and relative to other models.

iv. P-values of parameters estimates and goodness of fit tests

Hypothesis tests of parameter values determined whether an estimate was significantly different from zero. Goodness of fit tests judged the overall performance of the model fit. Typically, the level of significance was set at 0.05. There were occasional instances where the 0.05 criterion was not met, but there was little recourse for choosing another model. Judged in absolute terms.

v. Residual plots

Residuals were examined for homoskedacity and biasedness. Judged in absolute and relative to other models.

vi. Overly influential observations

Observations were judged on Cook's distance and leverage. When an observation was deemed overly influential, it was not reasonable to refit the model and exclude any overly influential observations given the limited data available. Judged in absolute terms.

Of these statistical metrics, residual standard errors, confidence intervals relative to effects concentration estimates, and confidence bands carried the most weight in determining the most appropriate model to be representative of an individual C-R dataset.

3. Determining Curve Acceptability for use in Taxonomic Adjustment Factor (TAF) or Mean Adjustment Factor (MAF) Derivation

The final curve fits that were selected for each of the quantitatively-acceptable toxicity tests were further evaluated and scored to determine whether the curves were: 1) quantitatively-acceptable for use, 2) qualitatively acceptable for use, or 3) unacceptable. To determine curve acceptability for use in deriving an acute or chronic TAF and/or MAF, each individual curve was reconsidered based on the statistical metrics described above. Instead of evaluating curves fits relative to other curve fits for the same data (as was previously done to select the most-robust curve for each test), curve fit metrics were used to assign each curve a score:

- 1 = **Quantitatively Acceptable Model**. Model performed well on most/all statistical metrics. Models that scored a 1 were used to derive TAFs and MAFs.
- 2 = **Qualitatively Acceptable Model**. Model generally performed well on statistical metrics; however, the model presented some characteristic(s) that may call estimates into question. Such models should be considered with caution. These problems consisted of any number of issues such as a parameter with a high p-value, poor goodness of fit p-value, wide confidence bands for fit or estimate interval, or residuals that indicated model assumptions are not met. Models that scored a 2 were used as supportive information and were included in TAF derivation if they provided data for listed species, or closely-related surrogates, that would otherwise not be available.
- 3 = **Unacceptable Model**. Model poorly fit to the data. Models should not be used for TAF or MAF derivation.

While the scoring system may contain a subjective component, it provides a classification mechanism to aid in evaluating models to inform their quantitative or qualitative use in a relatively repeatable manner. Individual model fits and the corresponding curve acceptability scores for each set of available C-R data are described in Appendix B. Please also see supplemental information: *NH3_Supplemental_Information_A* for acute C-R curves and model diagnostics.

Appendix D. Analysis of the Relationship between pH and Temperature on Acute Toxicity from USEPA Public Comment During the 2013 Ammonia 304(a) Criteria Derivation Process

The pH and temperature equations for total ammonia nitrogen (TAN) developed by EPA were evaluated in a preliminary analysis. Data from several additional studies with freshwater invertebrates not included in the determination of these equations were plotted against the fitted curves based on these equations to assess how well these equations predict the relationships of TAN toxicity to pH and temperature.

Based on a search of the ECOTOX database for additional ammonia and ammonium studies published between 1985-2009 not considered or used for developing the pH and temperature slope equations included in the 1999 AWQC document, four acute studies were found that could be used to evaluate the pH-TAN relationship (Straus et al. 1991, Hickey and Vickers 1994, Borgmann and Borgmann 1997, Wang et al. 2008), and two acute studies were found that could be used to evaluate the temperature-TAN relationship (Hickey and Vickers 1994, Sarkar 1997). None of these studies were used to calculate the initial pH or temperature equations for TAN toxicity for various reasons (e.g.; test duration, non North American species, TAN added as a formulation, publication subsequent to equation development). No additional chronic studies could be found to evaluate the chronic pH or temperature relationships. One additional study (Kitamura 1990) was excluded from evaluation of the pH-TAN toxicity relationship because of missing information regarding the form of the ammonia addition, whether the ammonia concentrations were based on nominal total NH_4Cl additions or measured NH_4-N concentrations, and the temperature of the study. Also, because this article was written in Japanese, it was impossible to address some of these questions.

Studies were used to assess the pH relationship if they consisted of more than one pH treatment with all other experimental conditions being held constant (e.g.; temperature, species, organism age, test duration, etc.). Conversely, studies were used to assess the temperature relationship if they consisted of more than one temperature treatment with all other experimental conditions being held constant. All reported EC/LC50s for a particular species were first converted to mg/L TAN. Subsequent procedure to assess the relationship between TAN and pH, and TAN and temperature, will be described separately.

Assessment of pH-TAN Toxicity Relationship

For the assessment of the pH relationship, converted LC50s (expressed as TAN) were then normalized to 25°C using the temperature-TAN toxicity equation: $(\mathrm{LC50}) * 10^{(0.036*(25\text{-}T))}$, where T=°C. Next, the degree of fit for a particular test pH relative to the pH-TAN equation was assessed according to the following procedure: first, the LC50 at pH 8 was determined for each point. This is required in order to evaluate the pH-TAN relationship for a particular dataset, as shown by equation 11 in the 1999 WQC for ammonia (USEPA 1999):

$$LC50 = LC50_8 * (\frac{0.0489}{1 + 10^{(7.204-pH)}} + \frac{6.95}{1 + 10^{(pH-7.204)}})$$

Where:

LC50 = LC50 at a given pH; and $LC50_8$ = LC50 at pH 8.

After solving for the LC50 at pH=8 for each test pH in a particular experiment, individual LC50s are normalized to pH=8 by dividing LC50 by the geometric mean of all $LC50_8$ for that experiment, so that $LC50_{8,25}$=1. Normalization to pH 8 allows data from multiple studies to be plotted against the same pH- TAN curve to illustrate the relative degree of fit at a particular pH to the existing equation. This approach is conceptually similar to the approach followed by Wang et al. (2008) to estimate the parameters for the pH-TAN toxicity relationship for their *L. siliquoidea* data, where they estimated the parameters R, pH_T, and $LC50_8$ from the log transformed equation 8 in the 1999 WQC for ammonia (USEPA 1999). Note that equation 11 is identical to the (untransformed) equation 8 after solving for R and pH_T.

$$\log(LC50) = \log(LC50_8) + \log\left[\frac{\frac{R}{1+10^{(pH_T-pH)}}}{\frac{R}{1+10^{(pH_T-8)}}} + \frac{\frac{1}{1+10^{(pH-pH_T)}}}{\frac{1}{1+10^{(8-pH_T)}}}\right]$$

Assessment of pH-Temperature Toxicity Relationship

For the assessment of the temperature relationship, LC50s converted to TAN were then normalized to pH=8 using equation 11 (above) from the ammonia WQC document (USEPA 1999). Next, the degree of fit for a particular test temp relative to the pH-TAN equation was assessed according to the following procedure: First, the LC50 at 25°C is deter/mined for each pH 8 normalized LC50 in a particular experiment using the following equation: LC5025 = LC50 * 10(0.036*(25-T)) where T=°C. Next, individual pH 8 normalized LC50 concentrations are divided by the geometric mean of all LC5025 values for a particular experiment (so that LC508,25=1) to facilitate comparisons from multiple experiments on the same figure.

Examination of figure 2 reveals that the current pH-TAN acute toxicity relationship equation effectively represents the pH-TAN toxicity relationship for P. antipodarum, B. sowerbyi, and V. bengalensis as tested by Hickey and Vickers (1994) and Sarkar (1997), respectively.

No other data (including for freshwater fish) have been published (or made available) since 1999 to evaluate the pH- and temperature-TAN toxicity relationships; thus, it appears that the current equations are still applicable for the 2010 draft AWQC update.

Figure 1. TAN LC50-pH relationship.

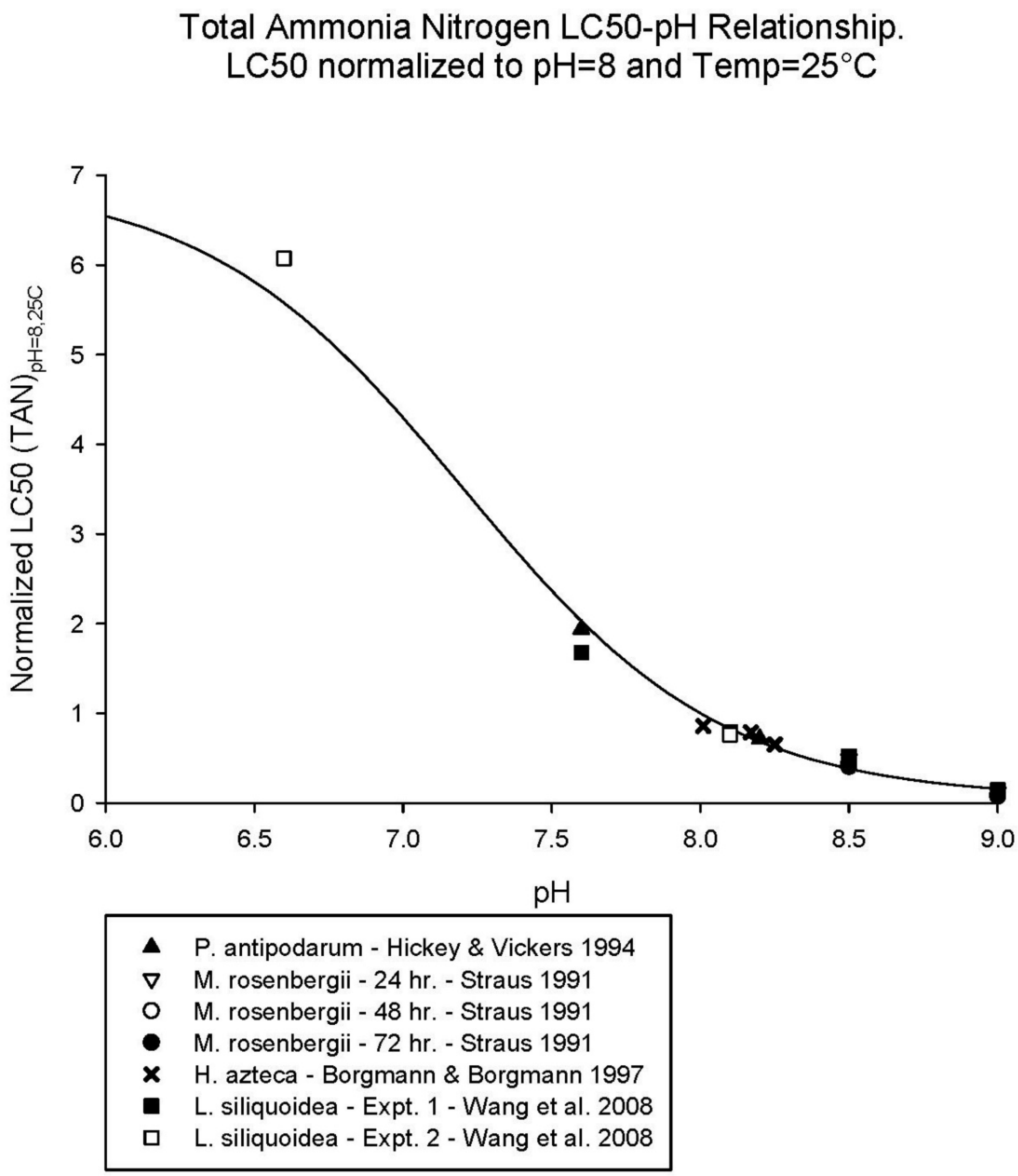

Figure 2. TAN LC50 – temperature relationship (Note: DAP = diammonium phosphate).